ELPI+™

USER MANUAL Ver. 1.12

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Excellence in Particle Measurements

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Precautions

Both the ELPI+™ and the external PC must be connected to the mains supply with an earth connector.
Do not switch on the ELPI+™ while the high voltage connectors of the charger are disconnected.
Do not touch the electrometer connections before making the ground contact. Static electricity may cause severe damage to the electrometer amplifiers.
Do not direct explosive gases through the ELPI+™ charger.
When the flush pump is used (e.g. while zeroing), the airflow through the device is altered and some flush air comes out from the sample inlet.
We recommend you to take necessary precautions to avoid accidental start up of the main pump or any external unit connected to the outputs during the power up sequence of the ELPI+™.

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1 INSTRUMENT DESCRIPTION

The ELPI+™ (Electrical Low Pressure Impactor) is a real-time particle spectrometer for measuring airborne particle size distribution in real-time. The operating principle is based on well known ELPI™ technology. The particles are first charged to a known charge level in a corona charger. After charging, the particles are size classified in a low-pressure cascade impactor according to their aerodynamic diameter. The impactor stages are electrically insulated and sensitive electrometers are connected to each impactor stage. The charged particles collected in a specific impactor stage produce an electrical current, which is recorded by the respective electrometer channel. This current is proportional to the number concentration of particles on each stage.

The ELPI+™ measures particles in 14 size fractions in the range from 6 nm to 10 µm. The 13 impactor stages operating in the range of 17nm - 10 µm collect the sample in a way that the collected sample can be chemically analyzed. The final stage measuring in the range of 6-17nm is a back-up filter stage.

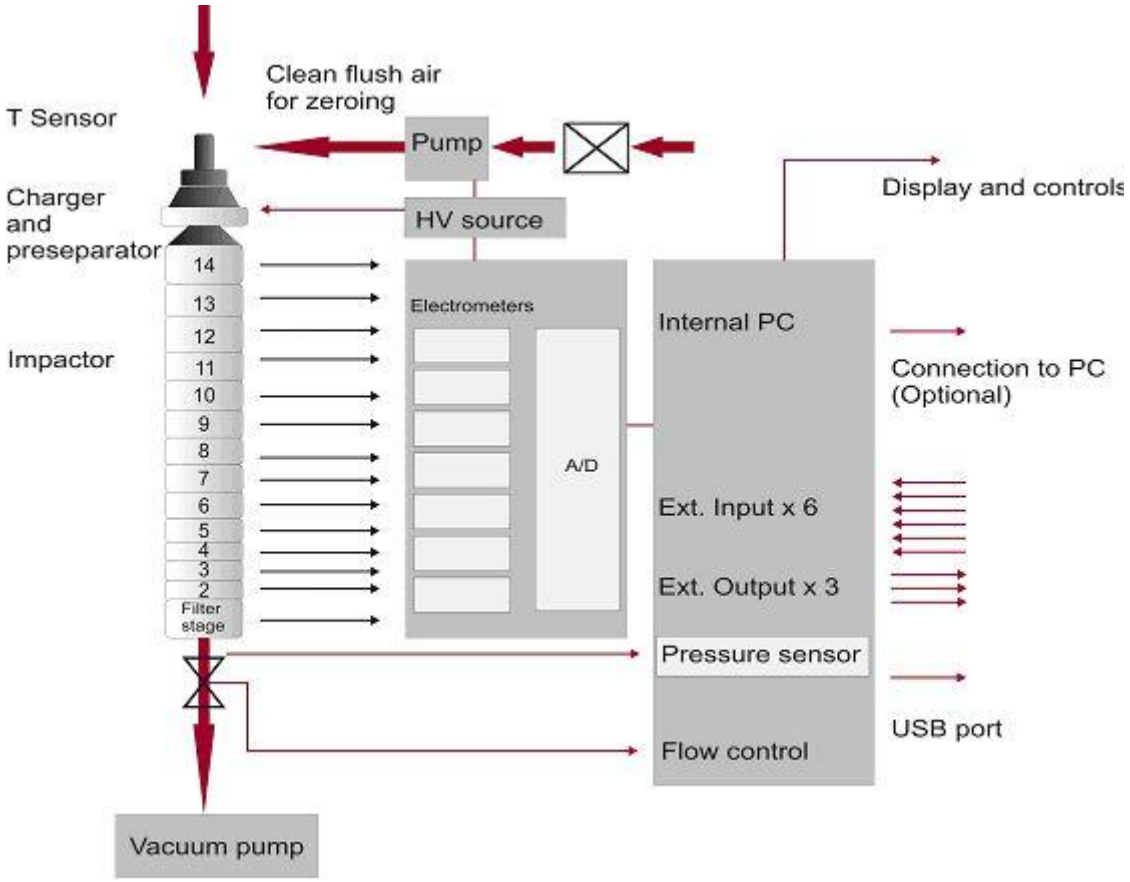


Figure 1: Operating principle of the ELPI+

The ELPI+™ unit can be used either as a standalone instrument or with an external computer. Automatic zeroing function in the ELPI+™ unit enables long term standalone operation. Through the ELPI+vi software the unit can be controlled remotely with TCP/IP or connection. 6 analog inputs and 3 analog outputs from/to ELPI+ ™ unit can be used for transferring information between measurement systems. The ELPI+ ™ internal software ELPInux and the ELPI+vi software can both be used to save the measurement results.

More information on the function of the ELPI impactor can be found in J. Keskinen, K. Pietarinen and M. Lehtimäki (1992), Electrical Low Pressure Impactor. *J. Aerosol Sci.,* Vol. 23, No. 4, pp.353-360.

2 SPECIFICATIONS

Measurement

Nominal air flow	10 l/min
Particle size range	0.006-10 µm
Number of channels	14 electrically detected + preseparator stage
Sampling rate	10 Hz

Operation conditions, instrument:

Ambient temperature	10–35 °C
Ambient humidity	0–90% RH, non condensing
Sample conditions	
Gas temperature	< 60 °C

Dimensions

Weight	15 kg without impactor, 22 kg with impactor
Dimensions	H400 x W420 x D220 (mm)
Dimensions of impactor	Ø65 x 300 (mm)
Inlet	G3/8" thread, G3/8" / NW16 and G3/8 / hose connection connectors included in the shipment
Outlet	G3/8" thread, G3/8" / NW16 connector included in the shipment

Electrical specifications

Electric power	100–250 V, 50–60 Hz, 200W (does not include pump or other accessories). External power supply is included in the shipment
Charger voltage	3.5 kV +/- 0.5 kV
Charger current	1 µA

Pump specifications

Pressure under the 1st stage	40 mbar
Pump for 10lpm ELPI+™	minimum 16 m3/h at 40 mbar abs. recommended 25 m3/h at 40 mbar

Computer specifications

Pentium processor MS-Windows XP™, Vista™ or 7™	
Connection to ELPI+™	RS-232 serial (USB –RS-232 adapter provided with the ELPI+™ instrument Ethernet

Analog channels

3 analog outputs	0 – 10 V
6 analog inputs	0 – 10 V

Nominal impactor specifications

Stage	D50% [μm]	Di [μm]	Number min [1/cm^3]	Number max [1/cm^3]	Mass min [μg/m^3]	Mass max [mg/m^3]
15	10					
14	6.8	8.2	0.10	2.4E+04	30	10000
13	4.4	5.5	0.10	2.4E+04	10	3000
12	2.5	3.3	0.15	5.4E+04	3.0	1000
11	1.6	2	0.3	1.1E+05	1.4	450
10	1	1.3	0.5	1.9E+05	0.7	210
9	0.64	0.8	1	3.5E+05	0.3	100
8	0.4	0.51	2	6.4E+05	0.1	50
7	0.26	0.32	3	1.2E+06	0.07	20
6	0.17	0.21	5	2.1E+06	0.03	10
5	0.108	0.14	10	3.7E+06	0.02	5
4	0.06	0.08	20	7.3E+06	0.005	2
3	0.03	0.042	50	1.7E+07	0.002	0.5
2	0.017	0.022	100	3.4E+07	0.001	0.25
1	0.006	0.01	250	8.3E+07	0.0004	0.13

See exact values from the impactor data sheet.

3 UNPACKING AND PACKING

When opening the ELPI+™ shipment for the first time, check that all the items listed below are in the package.

The ELPI+™ package contains:

- ELPI+™ unit including ELPI+™ impactor and charger assembly
- ELPI+™ carry case
- ELPI+™ Manual
- ELPI+VI™ Software Manual
- ELPI+™ Data sheet
- Power supply
- Accessory box:
  - Aluminium foils, 300pcs (CF-300)
  - Apiezon-L grease incl. mixing jar (AG-10)
  - 2m of sample hose (IPR-212)
  - Impactor collection plate tool (N1303)
  - Tweezers for handling of the impactor foils (IPR-403)
  - 2 pcs of 3/8” – NW16 connectors (IPR-110)
  - 1/2" - 3/8" connector for ELPI+ outlet (RA014-34-38)
  - Tube connector (RA030-12-38)
  - Spare charger needle
  - RS-232 Serial cable (IPR-509)
  - USB-Serial adapter (ELA-443)
  - Impactor leakage test tool
  - Teflon tape for vacuum connections
  - ELPI+™ flash drive including:
    - ELPI+™ and ELPI+VI™ Manuals
    - ELPI+VI™ Software
    - ELPIPluscalc data processing spread sheet
    - ELPI+™ Data sheet
- Vacuum hose including 2pcs of NW16 clamps and gaskets

If any of the items is missing from the shipment please contact your local ELPI+™ distributor or Dekati Ltd.

When packing the ELPI+™ unit for shipment the black transportation box should be used. See Chapter 3.5 for details.

3.1 Required external accessories

The following item is needed but not included in the shipment:

Vacuum pump

Minimum for 10 lpm ELPI+™	16 m^3/h at 40 mbar absolute pressure
Recommended	21 m^3/h at 40 mbar absolute pressure.

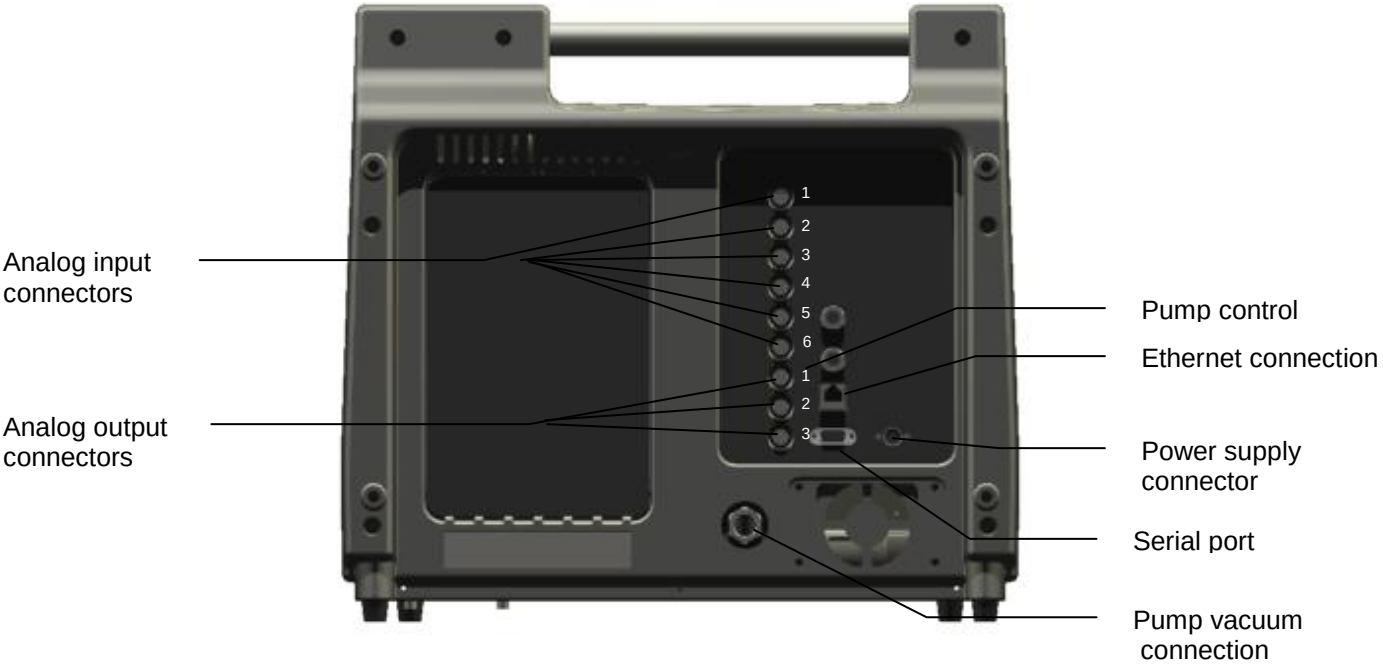
3.2 Recommended accessories

ELPI+™ can be used as a stand alone instrument, but it can also be used with ELPI+VI software. If ELPI+VI software is used a computer is needed.

External computer

Pentium or above, with Windows XP™ or Windows 2000 ™ or Windows 7 ™. Serial port or USB port for connection with the ELPI+. Also Ethernet connection available.

3.3 ELPI+™ housing and connectors



3.4 ELPI+™ components

3.4.1 Impactor

ELPI+™ impactor is used for particle size fractionating. It is a 14-stage cascade low-pressure impactor with a size range from 6 nm to 10 μm. Electrical detection

is applied to 14 stages while the first stage of the impactor is a pre-separator stage. All stages are electrically insulated from each other using PEEK™ insulators. The last stage of the impactor is an absolute filter stage.

3.4.2 Charger

Corona charger is used for particle charging before size classification in the impactor. Charger's ability to give a known charge to particles depends on the amount of ions it produces. The ion flow is controlled by the charger corona current. In ELPI+™ it is set to 1 μA. Charger corona current is the most important parameter for proper operation of the charger; the charger is current controlled, meaning that the voltage may change a little (+/- 1 kV) from its set-up value (3.5 kV). This is normal and usually there's no need of concern as long as the current remains constant.

Because a small amount of particles is collected on the charger walls via diffusion and electrical forces, an insulating layer may be formed on the inner surface of the charger walls. This layer increases the resistance within the charger hence more voltage is required to achieve the 1 μA current. Therefore a rise in the charger voltage may indicate a need to clean the charger.

3.4.3 Trap voltage

Trap voltage is a static DC field inside the charger after the corona discharge area. Trap field causes causing an electric field that removes charged molecule groups. Trap acts as a zeroth grade mobility analyzer or like a small electrostatic precipitator. In the ELPI+™ the trap voltage is 9 V (+/- 0.5 V).

3.4.4 Flush pump

Flush pump is used to feed clean, HEPA-filtered air into the charger and from there into the impactor. This way it is possible to check the offset levels of the electrometers or to stop collecting the sample from the measurement point. The amount of the flush air is larger than the impactor nominal flow rate so there is an air flow out of the ELPI+™ inlet while the flush pump is used.

The ELPI+™ inlet must not be closed when the flush pump is switched ON.

The HEPA filter that is used to clean the flush air is located inside the ELPI+™ housing, and should be changed every few years. ELPI+ calibration service that is made at Dekati Ltd includes the change of the HEPA flush filter.

3.4.5 Electrometers

14 electrometers are used to measure the current signals from the 13 impactor stages and the filter stage. The electrometers are placed inside the ELPI+™ electrometer box and each of them can measure current signals in the range of 0-500 000fA.

Zeroing is needed to adjust the offset levels of the electrometers. A very small offset error may lead to an unreliable measurement result; therefore the offset currents should always be checked before and after the measurement.

3.4.6 Pressure and temperature sensors

There are two pressure sensors and a temperature sensor in the ELPI+™ unit. The first pressure sensor is located in the ELPI+™ charger and indicates the

sample pressure; please note that when the flush is on pressure sensor reading is not accurate. Second pressure sensor is located after the ELPI+™ impactor. This pressure should be set to 40 mbar with the front panel pressure adjustment valve when measuring with the ELPI+™ unit.

The temperature sensor indicates the temperature of the electronics. There are also two thermocouple connectors behind the ELPI+™ unit. The thermocouples can be used to measure for example sample temperature. The sample temperature should not exceed 60 °C.

3.4.7 Pressure adjustment valve

The pressure adjustment valve is used to adjust the 40 mbar below the first stage. Turn clockwise to close and anti clockwise to open.

3.4.8 Analog input and output connectors

There are six analog input and three analog output connectors in the ELPI+ unit. The analog input connectors accept voltage signal from 0-10 V. The analog output connectors can have value total current, total number, total diameter, total area, total volume, total mass, PN10, PN2.5, PN1, PM10, PM2.5 or PM1. Total concentration means the total sum of all the stages. PN 10 / 2.5 / 1 means the particle number concentration below 10 µm / 2.5 µm /1 µm, respectively. PM 10 / 2.5 /1 means the particle mass concentration below 10 µm / 2.5 µm / 1 µm, respectively.

3.5 Packing the ELPI+™ for shipment

If it is needed to transport the ELPI+™ unit to another location, the following instructions should be followed in packing the ELPI+™ instrument to avoid damage to the instruments during shipping. For packing instructions of the ELPI+™ external pump, please see the pump manual:

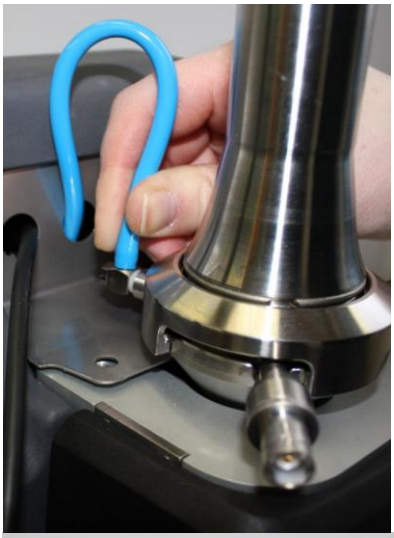
- Remove the ELPI+™ impactor-charger assembly from the ELPI+™ unit.
- Remove the ELPI+™ vacuum pump connector and possible inlet connectors.
- Place the ELPI+™ impactor and charger assembly and accessories in the separate compartments inside the black transport box.
- Place the black box into a cardboard box, or similar. Secure the packing with e.g. Styrofoam to make sure that the black box does not move inside the larger box.
- The ELPI+™ instrument should always be handled with care to prevent any damage to the instrument.

4 SETTING UP THE INSTRUMENT

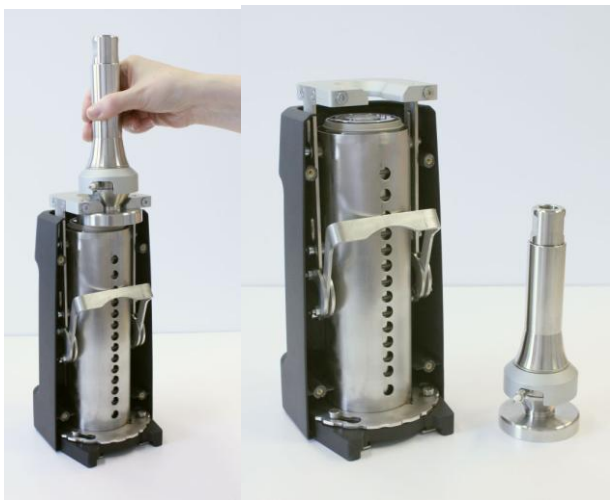
4.1 Disassembling and assembling the impactor

4.1.1 Disassembling the impactor

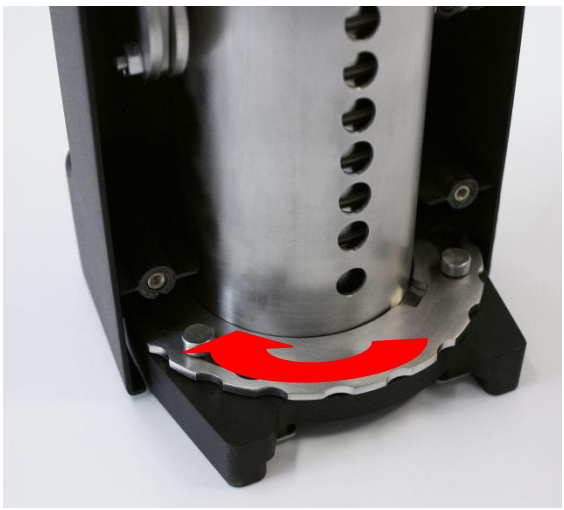
To release the impactor from the ELPI+™ housing, take off the charger, trap and flush pump connectors. Press the release button at the bottom of the impactor and pull the impactor from the housing

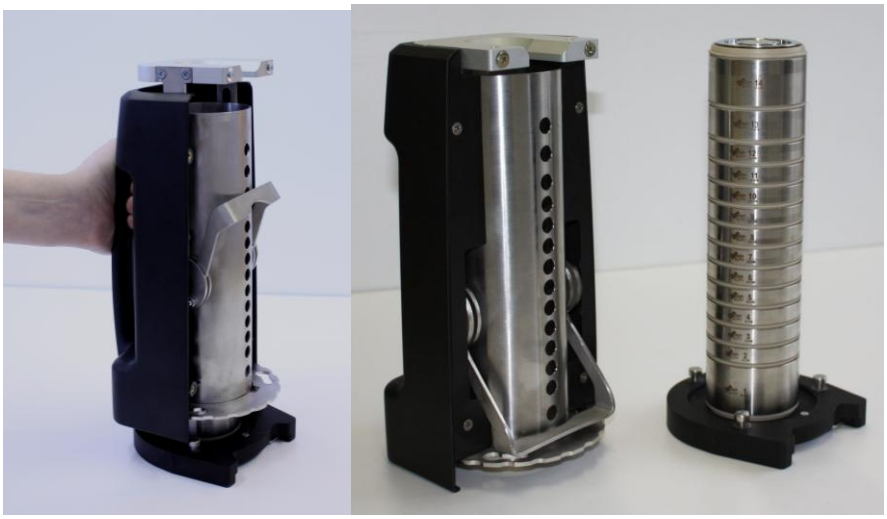


Lift the locking handle to the upright position and slide the charger with the pre-selector stage out from the impactor assembly.



Turn the locking ring at the bottom of the ELPI impactor clockwise and lift the impactor cover.





The collection plate and PEEK™ insulator of the stage 15 (attached with the charger) are placed on top of the impactor assembly. To disassemble the impactor remove first this collection plate and insulator. Remove the rest of the stages, collection plates and insulators.

4.1.2 Impactor assembling

Assembling the impactor is done in reverse order to disassembling. Each of the impactor stages has three parts: jet plate, PEEK™ insulator with o-rings and collection plate.

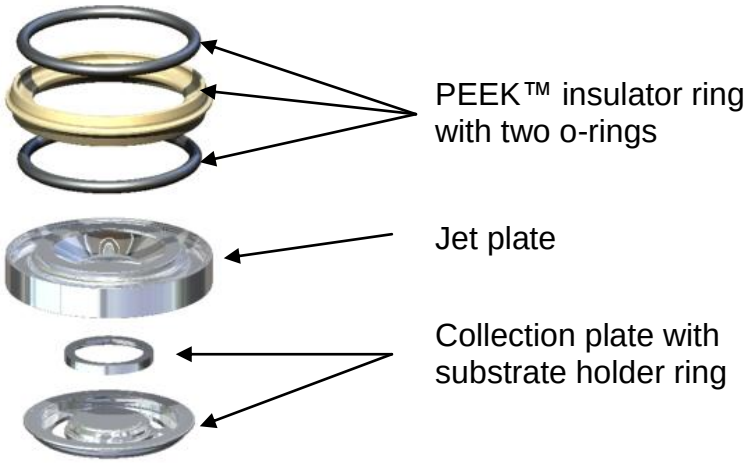


Figure 2: Construction of one impactor stage

The PEEK™ insulators have o-rings on both sides and the collection plate has a substrate holder ring to keep the collection substrates on their places.
The design of the filter stage is a bit different; it has only one part with insulators on each side. The filter stage consists of many layers of fine mesh that traps the particles below 17 nm (nominal). This part should not be disassembled nor does it need any servicing.

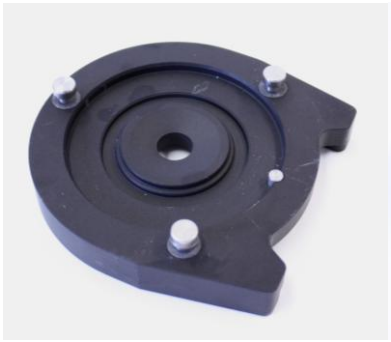
Figure 3: Filter stage

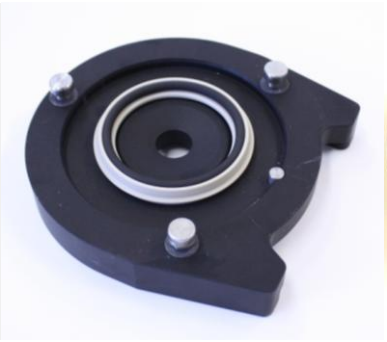
Before assembling the impactor, greased collection substrates should be inserted on the collection plates to ease the cleaning of the impactor after the measurement and to prevent bouncing of the particles during the measurement, please see section 4.2 Collection substrates for details.

All the jet plates and the collection plates are numbered.

The jet plates should always be in the correct, numbered order; number 1 at the bottom of the impactor and number 14 at the top of the impactor. The collection plates are identical and their order does not affect the electrical detection, but if chemical or other analysis is made of the collected samples, the collection plates should also be in correct, numerical order, collection plate number 2 under the jetplate 2 etc.. The filter stage does not have a collection plate, so therefore the numbering of the collection plates starts from number 2.

To start assembling the impactor, place the two o-rings on both sides of the insulators. Place the first insulator on the impactor base (see figure below). All of the insulators are identical and symmetrical, so the order or orientation of the insulators does not matter. Place stage number 1 (filter stage) on the insulator. Place an insulator on the filter stage and collection plate of stage number 2 on top of it. Place jet plate 2. Then continue with placing first the insulator, then collection plate 3, jet plate 3 etc. Finally, place the last stage (no 14) and then the last insulator and collection plate no 15.

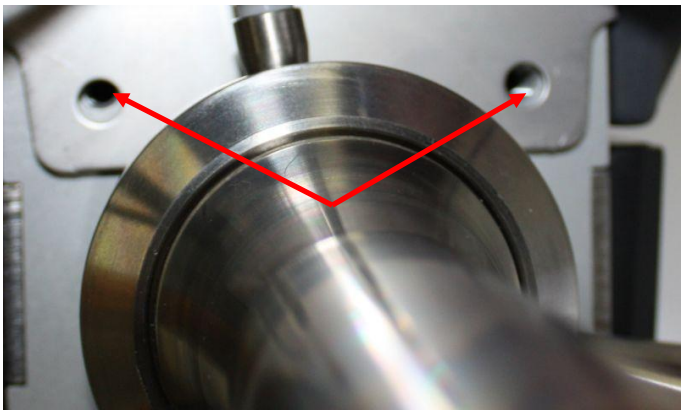




Put the impactor cover on the impactor assembly and turn the locking disc anti-clock wise. Hold the handle in upright position and place the charger assembly with the pre-separator stage on top of the impactor assembly. Press down the handle.

Place the charger-impactor assembly to the ELPI+™ housing and connect the charger and trap BNC connectors and the hose for the flush air.

Zero levels can be reduced by connecting two screws included in the shipment to the holes on the top plate and top part of impactor.



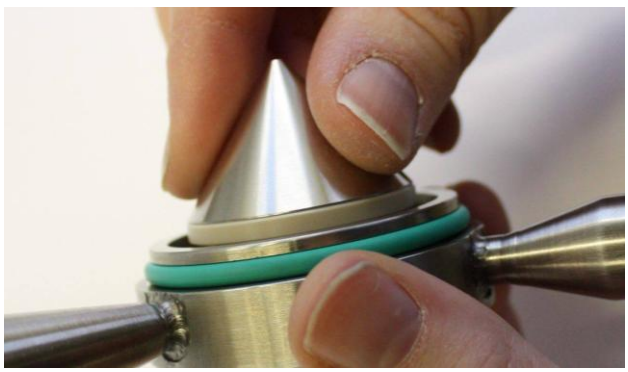
4.2 Disassembling and assembling the charger

Open the charger locking ring by turning it anti-clockwise.

Remove the pre- selector stage from the charger assembly. The two parts are kept together by an o-ring.

Remove the centre part of the charger from the inlet part by pushing the connector upwards. Be careful not to break the needle.

Continue disassembling by removing the trap cone. The trap is held in its place by a screw thread. Pliers can be used to help the disassembling. Careful handling is required; the trap part should not be scratched or damaged.



Remove the trap and HV BNC connectors. The needle is kept in its place by the connectors, after they are removed slide the needle carefully out of the charger assembly. The tip of the needle can easily get broken, so it should be handled carefully. Remove the trap connection ring and the needle.

Take off the charger inlet connector from the inlet part.

Remove o-rings from the charger inlet part, centre part and inlet connector

4.3 Collection substrates

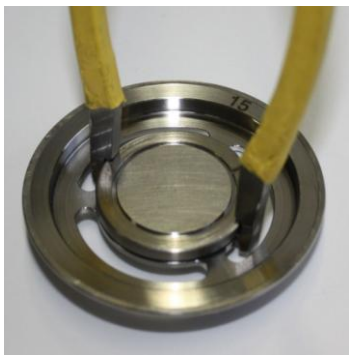
The collection substrates are used on the collection plates for two reasons; the use of the collection substrates enable gravimetric or chemical analysis after the measurement and the use of collection substrates makes the maintenance much easier. The collection substrates should be 25 mm in diameter, smooth and poreless and can be made for example from household aluminum foil. Other substrate materials are also available, e.g. polycarbonate foils are suitable for different types of chemical analysis. The maximum thickness for the substrates is 0.1 mm.

The most commonly used grease in impactor measurements is Apiezon-L, because of its purity and low evaporation properties. Dekati Ltd provides Apiezon-L for substrate greasing but other types of greases may also be used as long as the grease has low evaporation characteristics even in low pressures (min 40 mbar abs), a thin and smooth layer of used grease can be applied on the substrate, and the grease has low enough viscosity so that the air flow inside the impactor does not blow the grease out of the impactor collection substrates. For high temperature applications above 150 °C Dekati provides Apiezon-H grease.

4.3.1 Inserting the collection substrates

1. Disassemble the impactor and separate the stages as explained in Section 4.1.
2. Remove the substrate holder rings from the impaction plates. You can use the substrate-positioning tool for this, or simply fingers if contamination of the collection substrates is not a matter of concern.

Take the substrate positioning tool and grab the collection plate so that the substrate holder ring fits in the big holes of the tool.



Squeeze the tool gently and pull up while pushing the collection plate down gently.

When using the substrate positioning tool, do not squeeze it too hard when trying to remove the substrate holder rings. Squeezing it harder makes it even more difficult to remove the substrate holder ring. If you are unable to remove the substrate holder ring, try re-positioning the tool around the substrate holder ring.

3. Place the collection substrate carefully on the impaction collection plate. Make sure that the foil is in the centre of the collection plate

4. Place the substrate holder ring in its place. Take the substrate holder ring into the tip of the substrate positioning tool and push it down until it clicks in its place. Check that the collection substrate is smoothly in its place

To remove the collection substrate after the measurement, use again the substrate-positioning tool.

4.3.2 Greasing the collection substrates

1. The collection substrates can be greased for example with Apiezon-L grease (high purity, minimal evaporation) dissolved in carbon tetrachloride, toluene or acetone. Dissolve Apiezon-L grease in solvent by adding the grease to the solvent little by little until the liquid is nearly opaque (grease/solvent ratio about 1/30-1/20). (**Consult your chemical material supplier for the proper handling of hazardous chemicals**)
2. Grease one substrate using for example a fine brush. Keep the edge of the substrate clean (the part that remains under the substrate holder ring). If the foils are not weighed or analysed after the measurement, it is usually easier to grease the foils after they have been placed on the collection plates.
3. Another option is to use the Dekati collection substrate spray and stencil for greasing 15 substrates at the same time (See Figure below). More details on the substrate spray can be found in the substrate spray manual.
4. Wait a couple of minutes so that the solvent has evaporated.
5. Check that a thin and smooth layer of grease is left on the substrate. If the layer is not good, add some amount of grease in the solvent and repeat the procedure.
6. Grease the remaining substrates

4.4 Leakage check

Because the last stages of the ELPI+™ operate in low pressure, it is important that the impactor does not leak. Leakage in the instrument changes the sample air-flow, impactor operation pressures and the particle cut-off diameters of the impactor stages. These alterations will cause errors in determining the aerosol size distribution and concentration. Therefore, it is important to conduct the leakage test after each time the impactor is assembled.

ELPI+™ is equipped with an internal pressure sensor; reading of the pressure sensor can be found from the ELPI+™ display : “Pressure” indicates the pressure after the impactor.

To perform the ELPI+™ leakage check:

1. Connect the pump to the ELPI+™ outlet as in a normal measurement.
2. Turn on the pump. You should see the internal pressure sensor reading change on the ELPI+™ display.
3. Read the pressure reading and adjust the pressure adjustment valve to get a reading of <40 mbar.
4. Close tightly the inlet of the charger using e.g. a leakage check tool provided with the ELPI+™ unit or an eraser. After a while, the pressure should reach the end pressure of the pump (check this from pump specifications).
5. Close the pressure adjustment valve in the ELPI+™ unit front panel.
6. The pressure should not rise more than 20 mbar per minute. If the leakage is less than this, you can continue with the instructions given in section 4.5.
7. If you fail to get the values above, check that that the impactor is properly positioned in its support.
8. If a leakage still exists, check:

    - that the impactor is properly assembled (see Section 4.1)
    - that the charger is properly assembled (see section 4.2)
    - O-rings of the impactor insulators are properly positioned
    - O-rings of the impactor insulators are clean. A small amount of vacuum grease can be applied on the O-rings.
    - contacting metal and insulator surfaces are clean and intact
    - the vacuum gasket under the ELPI+™ impactor is properly positioned and the NW16 gasket at the ELPI+™ outlet in the NW16 flange connections is properly positioned
    - that teflon tape has been applied on the ELPI+™ vacuum connections to seal them.

4.5 Electrometer zeroing

Zeroing is needed to adjust the measured current for the electrometers' bias current. Different bias currents are caused for example by different operation conditions, like ambient temperature.

Flush pump

Zeroing has to be performed before ELPI+™ is used for measuring. If the measurement period is long, zeroing should be checked regularly, especially if ambient temperature conditions change during measurement. Zeroing can either be performed manually or the zeroing period of the ELPI+™ can be preprogrammed to a certain time interval; more detailed instructions for this can be found in the ELPI+™ internal software section of this manual. The flush pump can be used to check the offset currents. The flush pump is located inside the ELPI+™ unit, and it pumps clean, HEPA filtered air through the instrument. This way electrometer readings at zero concentrations can be checked.

When the flush pump is switched ON, the airflow comes out of the ELPI+™ inlet. The ELPI+™ inlet should be open at all times when the flush pump is switched ON to prevent any damage to the flush pump. The flush pump can also be used to keep the ELPI+™ clean between the measurements; when the flush is ON, there is no sample collected into the ELPI+™ impactor.

The flush pump can be switched on from the ELPI+™ unit display, using the push buttons or from the ELPI+vi software.

Zeroing

Before zeroing the ELPI+™ should reach its stable operation temperature, and the measured currents must be properly stabilized. It is therefore necessary to switch on the unit at least half an hour before the zeroing and measurement. Before starting the zeroing procedure, the charger is adjusted to normal measurement settings, impactor low pressure is adjusted to 40 mbar and the flush pump is switched on to let a flow of clean and filtered air go through the instrument. At this point, it is often useful to look at the current values in different impactor stages. This can be done e.g. by looking at the ELPI+™ display: the default graph when the ELPI+™ is turned on shows the current values on each impactor stage as a function of time. In the beginning, the current values may drift up or down. After they have stabilized, the zeroing can be started. Note that the current measurement always has some noise. The zeroing can be started when the *drift* of the electrometers has stopped. After successful zeroing, the current values (noise levels) with flush pump ON (or with filtered inlet air) should not exceed +/-10 fA.

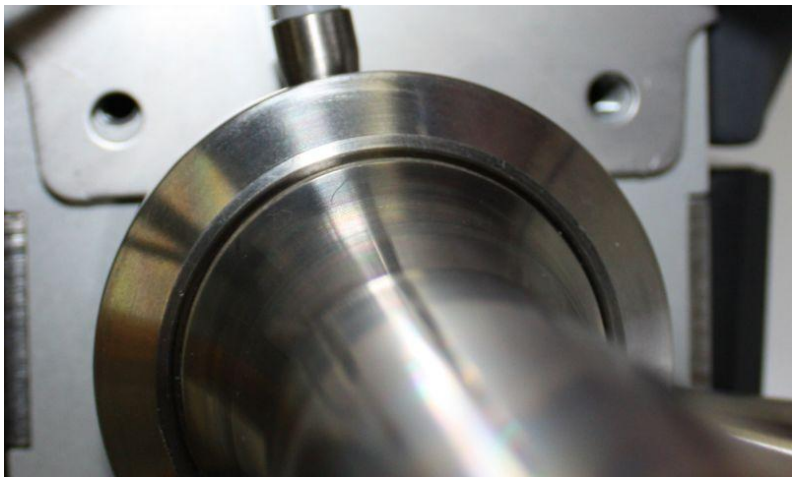
Zeroing process:

1. Start the flush pump. Press the Menu button in the ELPI+™ display and select Flush ON. Alternatively, the Flush can be started also from the ELPI+vi software.
2. Before starting the actual zeroing, wait until the current values are stable. There is always some noise in the electrometer readings but there should be no drift in the signal before the zeroing in started. The current values can

be checked from the first screen (All currents display) of the ELPI+™ unit or from the ELPI+vi software Data display – Common window.

3. Press the Menu button in the ELPI+™ display twice to go to the Main menu window. Choose Control, Choose Start Electrometer calibration. When the electrometer calibration is chosen, the system does not respond to any commands before the calibration is done. Alternatively, the zeroing can be started from the ELPI+VI software with the Zero button. Zeroing can take few minutes.
4. After the zeroing is finished, check that the zero levels are within acceptable limits (+-10 fA) with Flush ON. The zero levels should always be checked from the raw current values.
5. If the zeroing has not been successful, ie. the zero levels are not within acceptable limits, leave the flush on for a longer period of time to stabilize the current signals, and perform the zeroing again. If it is still unsuccessful clean the impactor as described in Chapter 6.
6. If the ELPI+™ unit is used with the ELPI+vi™ software, zero button can be used for zeroing the instrument. See details from the ELPI+vi™ manual

Zero levels can be reduced by connecting two screws included in the shipment to the holes on the top plate and top part of impactor.



5 MAKING A MEASUREMENT

5.1 Instrument setup

Quick start-up instructions for an ELPI+™ measurement are given in this chapter. For more detailed instructions on the different procedures, see respective chapters.

1. Check that the impactor and charger are clean. If cleaning is needed, follow the instructions given in chapter 6. Assemble the impactor and the charger; use suitable collection substrates in the impactor.
2. Place the charger-impactor assembly to the ELPI+™ housing. Press the assembly firmly into its place so that the release button at the bottom of ELPI+™ unit is locked. Connect the charger and trap BNC connectors and the hose for the flush pump.
3. Connect the power supply to line voltage.
4. Connect the vacuum pump to the ELPI+™ outlet with the vacuum hose.
5. Switch on the ELPI+™ power from the front panel by pressing the ON button for few seconds.
6. Select the correct impactor serial number in the setup window if you have multiple impactors (see section 7.2.15)
7. Perform the leakage test (see section 4.3).
8. Use a metering valve in the ELPI+™ unit front panel to adjust the impactor low pressure to 40 mbar.
9. Turn on the charger.
10. Perform the electrometer zeroing with flush on (see section 4.5).
11. Connect the ELPI+™ inlet to the desired sample line. Pay attention to the sampling conditions.
12. Start saving the data from Menu 2/3. For details on saving and changing the save parameters, see chapter 7 and ELPI+VI™ User manual.

5.2 Gravimetric measurements

ELPI+™ instrument can be used to make gravimetric impactor measurements as well as gaining real-time data of the sample concentration. The gravimetric analysis can only be performed from the impactor stages; the filter stage can not be gravimetrically analyzed.

Gravimetric measurements are made by following procedures outlined below:

1. Grease the collection substrates.

2. Weigh the substrates using a microbalance (recommended sensitivity 10 micrograms or better).
3. Place substrates on the impaction plates.
4. Assemble the impactor.
5. Switch on the pump and set the impactor outlet pressure to 40 mbar.
6. Collect the sample and record the sampling time.
7. Switch off the pump.
8. Disassemble the impactor. Remove the collection substrates.
9. Weigh the collection substrates.
10. Calculate the mass collected on the substrates.
11. Calculate distribution.

Particle losses always occur in the ELPI+™ charger when the charger has been switched on. These losses are taken into account in the ELPI+™ calculation, in the charging efficiency curve, and therefore need not be worried about in a standard ELPI+™ measurement. When gravimetric measurements are made with the ELPI+™ impactor, however, these losses always need to be taken into account in the final results. Therefore the gravimetric impactor measurements are only made when the charger and trap has been switched OFF. In this setup, no ELPI+™ real-time data is received from the instrument. The software shows the natural charge of the sample.

Note: If electrical detection (charger and trap ON) is also conducted during the collection of the mass sample, particles are collected in the charger by electrical mechanism. Measured masses need to be corrected for these losses.

5.3 Chemical analysis

The 14 upper stages, 13 impactor stages and the pre- separator stage, of the ELPI+™ impactor collect the sample on collection substrates so that the samples can be chemically analyzed. When the sample has been collected, each size fraction can be individually chemically or physically analyzed. The sample on the filter stage can not be used for chemical analysis.

When making a chemical or physical analysis proper sample handling must be used to reduce the risk of contamination. The contamination risk must be reduced by careful preparation and work procedures. Before placing the collection substrate on the collection plates, the collection plates must be carefully cleaned. Greasing of the collection substrates and assembling of the impactor is preferably done in a clean room. When disassembling and moving the impactor, contamination is prevented by using a clean transport case. In a laboratory, samples are stored in a dry, dark and cool place. Samples are handled in a clean room.

The collection substrate must be chosen in consideration of the analysis method. Collection substrates can be manufactured from different materials and are available for example in aluminum, PTFE (Teflon), glass fibre and polycarbonate.

Polycarbonate substrates are well suited for different chemical analysis; these substrates are also available from Dekati Ltd.

5.4 Blank samples

Whenever conducting gravimetric measurements or chemical analysis, use of blank samples is recommended. Blank samples are handled exactly the same way as the real measurement samples but the measurement is made using a HEPA filter at the instrument inlet, so no sample is collected on the collection foils.

With blank samples the effect of substrate handling can be taken into account.

6 MAINTENANCE AND SERVICE

Particles are collected inside the ELPI+™ impactor when measurements are conducted. There are also particle losses inside the charger and particles are collected on the charger surfaces. Therefore, **both the charger and the impactor need regular cleaning**. The impactor should be kept clean to avoid any changes in the impactor cut points and to avoid the bouncing effect. If the charger voltage rises above 4.5 kV it is usually indication that the charger should be cleaned.

The ELPI+™ service program is divided to four parts:

Daily service

Weekly/Monthly service

Yearly service

ELPI+™ calibration service

Time interval of the services depends on how frequently the ELPI+™ unit is used for measurements and how high concentrations are measured.

The daily, weekly and yearly first service procedures are done by the user of the instrument. ELPI+™ full calibration service is conducted at Dekati Ltd. or by official Dekati distributor. The recommended time interval for ELPI+™ calibration service is 2-3 years.

6.1 Daily service

Daily service includes changing the collection substrates and cleaning of the charger and impactor by wiping the surfaces. When wiping the surfaces of the impactor and charger use a damp tissue with a suitable solvent. The tissue should not release any fibres on the surfaces.

Also the leakage check and electrometer zeroing should be done before each measurement or when the impactor has been removed from the ELPI+™ unit.

6.1.1 Cleaning procedure

1. Disassemble the impactor as described in section 4.1.1. Remove the used collection substrates.
2. Remove the pre-separator stage and the inlet part of the charger, see section 4.2.
3. Wipe all parts using a suitable solvent. Choose the most suitable solvent considering the type of particles you are measuring. Salt particles dissolve best in water, whereas hydrocarbon particles dissolve better in

hydrocarbon-based solvents. It is recommended to wipe the parts last with isopropanol to ease the drying.

4. Let the parts dry before assembling.
5. Assemble he impactor and the charger.

6.2 Weekly/Monthly service

Weekly service includes the changing the collection substrates and cleaning of the charger and impactor in an ultrasonic bath.

6.2.1 Cleaning the impactor

1. Disassemble the impactor as described in section 4.1.1.
2. Remove the used collection substrates.
3. Take off the o-rings from the insulators.
4. Place the parts (except o-rings) to an ultrasonic bath with a suitable solvent; wash the insulators separately. Choose the most suitable solvent considering the type of particles you are measuring. Salt particles dissolve best in water, whereas hydrocarbon particles dissolve better in hydrocarbon-based solvents.
5. Let the parts dry properly before assembling. It is recommended to use isopropanol as the last solvent, because it eases the drying.

6.2.2 Cleaning the charger

1. First disassemble the charger as described in section 4.2.
2. All the parts except for the BNC connectors and o-rings can be washed in an ultrasonic bath with a suitable solvent. Choose the most suitable solvent considering the type of particles you are measuring. Salt particles dissolve best in water, whereas hydrocarbon particles dissolve better in hydrocarbon-based solvents.
3. Let the parts dry properly before assembling. It is recommended to use isopropanol as the last solvent, because it eases the drying.

Every time the charger has been disassembled and is being assembled again, electrical contacts need to be measured. The contact should be measured between the needle and the HV connector, between trap and the trap cone.

6.3 Yearly service

Check the impactor flow rate with e.g. laminar flow element. The measured value should correspond to the impactor flow rate value on the data sheet. Inlet pressure

of the impactor should be 1013.3 mbar and the low pressure under the first stage 40 mbar when the flow rate is measured.

If the impactor flow rate is smaller than the value on the data sheet, it is usually a sign that the impactor cleaning has not been efficient enough and the jets on the impactor jet plates have been clogged. Try using different solvent with the ultrasonic cleaner. Pressurised air can also be used for cleaning the jets.

6.4 ELPI+™ standard service

In order to ensure proper operation of ELPI+™ a more thorough service should be done every other year or three years. The need for the service depends on how frequently ELPI+™ is used. The service is done by the local distributor or Dekati Ltd.

Standard service includes:

- Arrival inspection including reference test and general operation check in instrument's arrival condition
- Cleaning
- Calibration of electrometers
- Calibration of pressure sensors
- Calibration of temperature sensors
- Calibration of trap and corona voltage and corona current
- Impactor pressure calibration
- Flush pump filter change
- Final check of operation
- Reports: arrival inspection, service and final check

7 ELPI+™ INTERNAL SOFTWARE - ELPINUX

ELPI+™ can be used as a stand-alone unit or with the ELPI+™VI software installed on a separate computer. This chapter describes the use of ELPI+™ internal software, ELPInux. For using the ELPI+™ unit with the ELPI+VI software, see the ELPI+™ software manual. The data collection and saving can be independently controlled from both the unit and the software, both also include the data calculation so changing a setup value in the software does not change the result in the ELPInux and vice versa.

The calibration parameter file of the ELPI+™ and the impactor has been uploaded to the ELPI+™ unit at Dekati Ltd. before shipment. The calibration parameter files include the cutpoints of the impactor stages and the charger calibration curves, for detailed information see chapter 8. If multiple impactors are used in the same ELPI+™ unit select the correct impactor number from the ELPInux software (See 7.2.15)..

There are four push buttons in the ELPI+™ unit front panel, the rightmost one is used to turn the unit ON and OFF, but it is also used for other functions, the current function is seen at the bottom of screen.

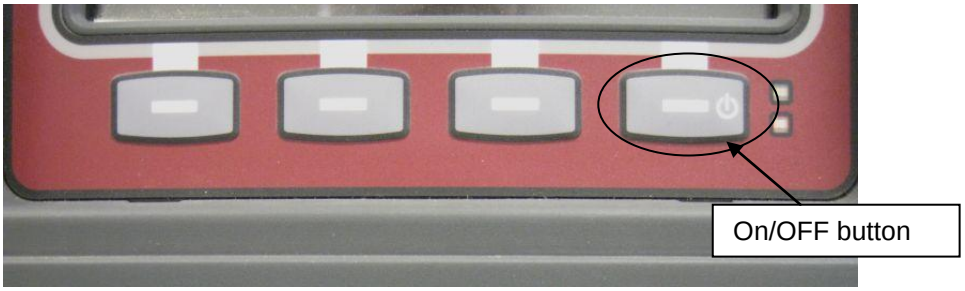


Figure 1: Four push buttons below the ELPI+ screen

7.1 Distribution charts

When the system starts, a multi view is displayed on the screen showing the current distribution chart, the time history chart and the data values.

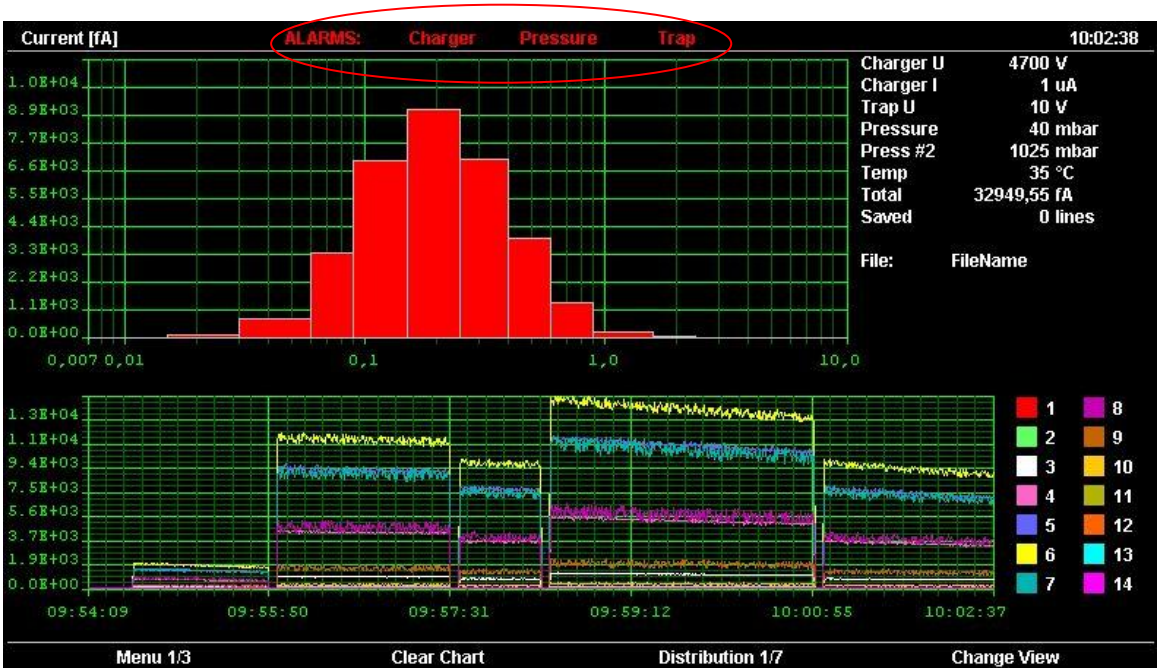


Figure 2: Distribution/time history/data –view, alarms shown on the top of the screen with red

The upper left corner of the display shows the selected distribution (Current / Number / Diameter / Area / Volume / Mass / RawCurrent). Current shows the corrected currents, RawCurrent shows currents without the correction.
Time history chart shows the currents from all stages or the total concentration change over time. The maximum number of samples shown on the screen is 1024 samples.

The alarms are shown above the distribution chart: the status of the charger voltage (Charger), the status of the impactor low pressure (Pressure) and the status of the trap voltage (Trap). Red text appears on the screen, see picture above, if the measured value of the variable is outside limits. If there are no alarms no text is displayed.

Also some important parameters describing the status of the ELPI+™ unit are shown on the right hand side of the screen:

Charger	Charger voltage [V]
Trap	Trap voltage [V]
Pressure	Impactor low pressure [mbar]
Press#2	Sample pressure [mbar]
Temp	Thermocouple temperature [°C]

Total	Total sum of all channels (unit depending on selected moment)
Saved	Number of saved lines (if the saving is on)
File	Name of the save file (ELPI_yyyymmdd_hhmmss.dat)

The system time is shown in the upper right corner of the display. The time can be changed through the ELPI+VI software, please see the software manual for details.

7.2 Navigation

Below the time history chart are four navigation options, which can be operated with the four push buttons below the display.

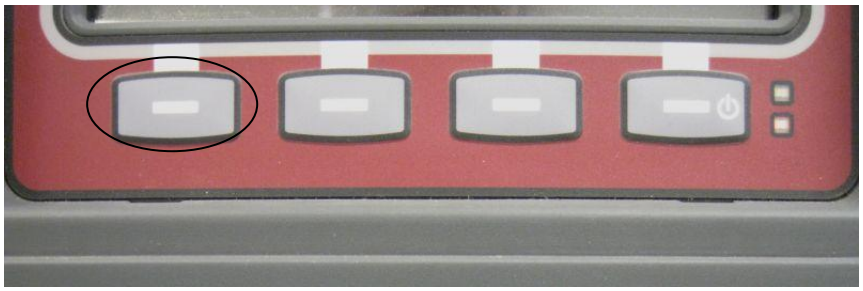


Figure 3: Four push buttons with Menu button circled on the left

With the **Menu** –button three different views (Menu 1/3, Menu 2/3 and Menu 3/3) can be selected. Each of these views has different functions for the other three push buttons.

7.2.1 Menu 1/3

Figure 4 on the next page shows the Menu 1/3 view displayed at the startup of the system. The current chart with the corrected currents and the selected distribution.

Clear chart

Clear Chart -button clears the time history chart. The maximum number of samples shown in the time history chart is 1024 (with 1 s sampling interval, the maximum length of time axis is about 17 minutes). When the data buffer is full, the oldest samples are removed from the display, and the time chart is updated so that the newest values are shown on the right. Time stamp used is the system time (seen in the upper right corner of the display).

Distribution

Distribution -button changes the moment shown in the distribution chart and in the time history chart. Seven different moments are available with the following distribution charts.

Current (1/7) > Number (2/7) > Diameter (3/7) > Area (4/7)> Volume (5/7) > Mass (6/7) > RawCurrent (7/7) > Current (1/7) >etc

Current is the corrected current, which takes into account the fine particle losses according to the fine particle correction algorithm. The fine particle correction algorithm is explained in detail in Virtanen, A., Marjamäki, M., Ristimäki, J., Keskinen, J. (2001). Fine particle losses in electrical low-pressure impactor, Journal of Aerosol Science, vol 32, pp 389-401.

RawCurrent shows the measured current without the fine particles correction algorithm.

Number shows the number distribution and the total number concentration.

Diameter is the total diameter of the particles; the diameter used for calculation is the channel geometric midpoint, Di

Area is the total area of the particles, channel geometric midpoint Di is used for the calculations.

Volume is the total volume of the particles, channel geometric midpoint Di is used for the calculations

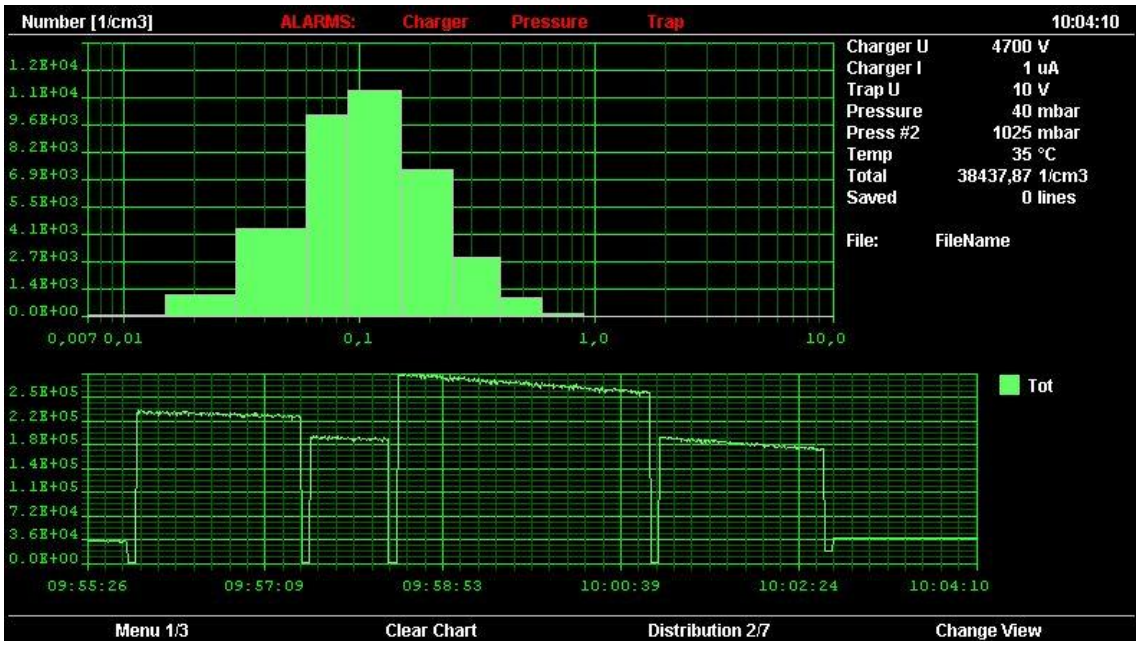


Figure 4 Multi view with the number distribution selected.

If Current or RawCurrent has been selected, all measurement channels are displayed in time history chart. With the other moments only the total sum of all measurement channels is displayed.

The calculation? of the moments is based on the measured raw currents or on the calculated corrected currents,which take the effect of fine particle losses in the impactor taken into. The currents used in the calculation can be selected in the Display-menu (see details in Section 7.2.17).

Change View

When the **Change View** -button is pressed the chart type shown on the display is changed in the following order:

Multi view > Distribution view > Time history view > Multi view > etc.

Multi view is combination of both the Distribution and time history view

Distribution view displays the distribution of the selected moment. The moment can be selected through the Distribution- button.

The time history view displays the time history of the selected moment. If Current or RawCurrent has been selected, the currents of all channels will be displayed. If other moment (Number, Diameter, Area, Volume or Mass) has been selected, the total sum of all measurement channels is displayed.

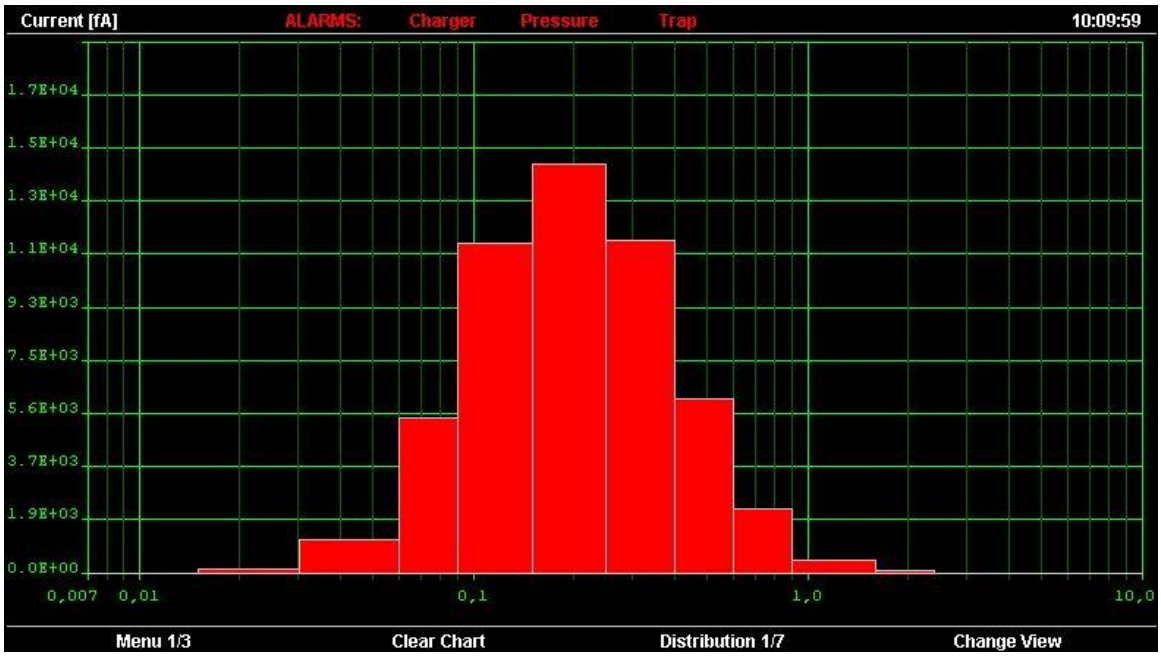


Figure 5: Current distribution view.

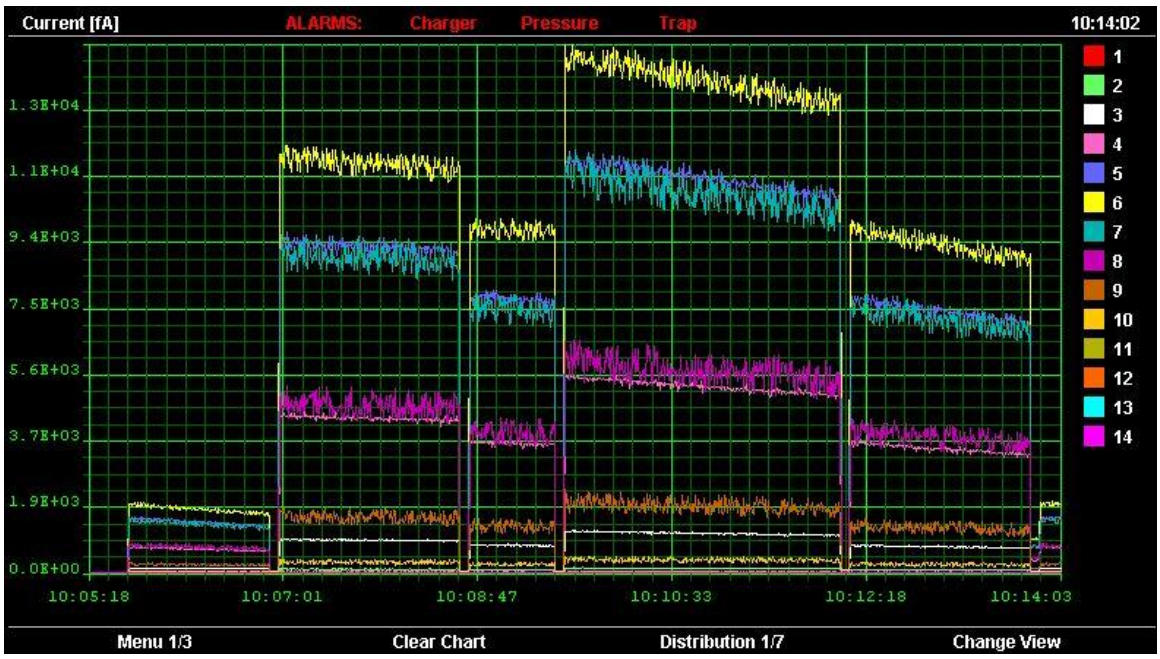


Figure 6: Time history view of currents.

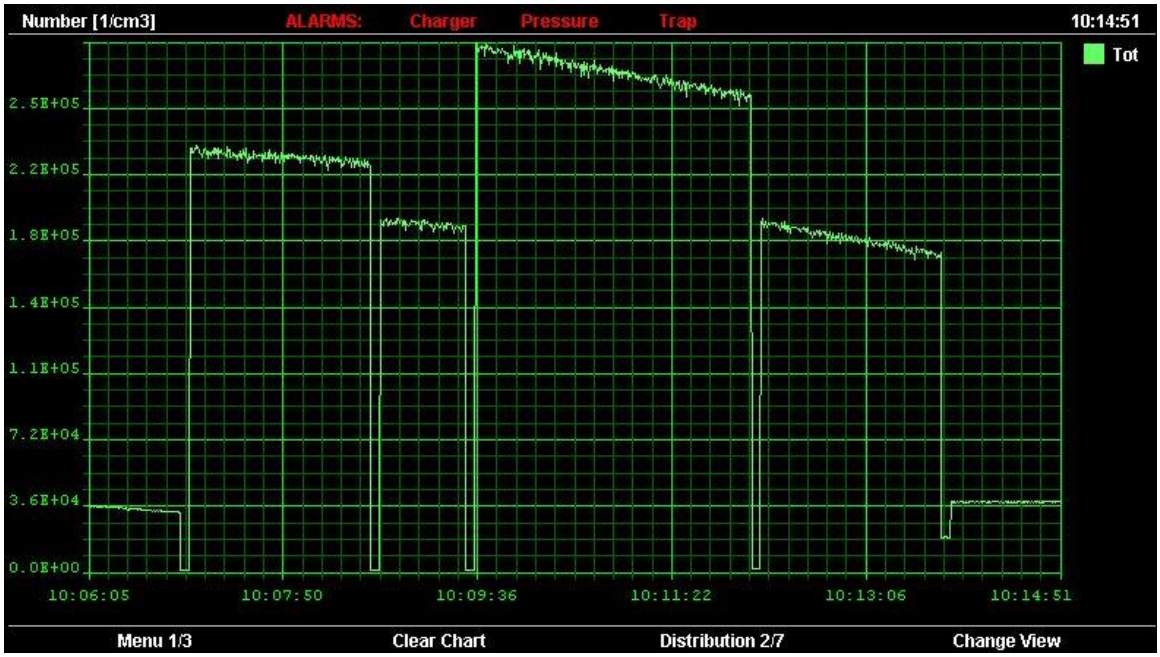


Figure 7: Time history view of total number of particles.

7.2.2 Menu 2/3

When the Menu -button is pressed once the functions of the push buttons change.

Charger button controls the charger and trap voltage ON and OFF.

Flush is used to control the flush pump that feeds HEPA filtered air through the charger and impactor unit.
The saving of the data to the USB can be started and stopped by pressing the **Saving** button. The USB memory should first be mounted, see section Data File.

For details and changing the save parameters please see section 7.3 Data file description.

7.2.3 Menu 3/3

When the Menu button is pressed second time the display is changed to a menu display. In this display the four possible control actions shown at the bottom of the display are:

Back
Open/Modify
Up
Down

The controls are selected with the push buttons below the display. With the **Back** button it is possible to return one level backwards in the menu tree. When the **Back** –button is pressed in the **Main Menu** –view, the display returns to the chart view (Menu 1/3).

Figure 4: Main Menu view

Use the Up and Down buttons to move the cursor and Open/Modify button to select the item. The menu options are shown at the left part of the display. If there are submenus a **>>** -prompt is shown after the menu item. In the above figure all items of the Main Menu have submenus, the Data file menu has been selected with a cursor.

7.2.4 Changing or setting the value

If the possible options of the menu item are of *letter* type, there are two possibilities:

1. If there are only two alternatives (On/Off, Yes/No, True/False), the value will be changed immediately after pressing the **Open/Modify** button.

2. If there are several alternatives, a new window will be opened showing a menu of the possible choices. The cursor can be moved in the menu with the **Up**- and **Down**-buttons. The selection is made by pressing the **Open/Modify** button, which returns the control to the upper menu level. Pressing the **Back** button returns to previous menu, but no change will be made.

Changing a parameter, when there are several possible values.

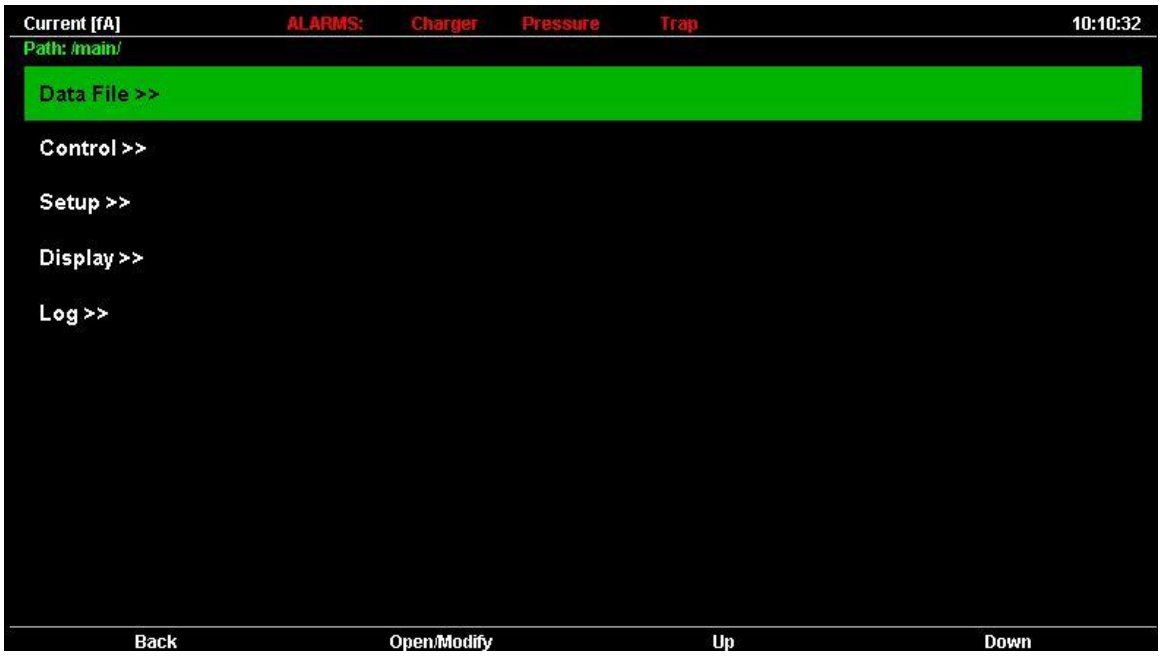
If the possible options of the menu item are of *number* type, a new window will be opened when the **Open/Modify** button is pressed. The new window shows the current value of the parameter and the possible control actions:

The moving of the cursor is made with **Up**- and **Down**-buttons and the selection of the menu item is made with **Open/Modify**-button. By choosing **Increment** and by pressing **Open/Modify** once, the value of the parameter is increased with a step set forehand in the program. By choosing **Decrement** and by pressing **Open/Modify** once, the value of the parameter is decreased with a step set forehand. If the Open/Modify-button is pressed continuously, the value of the parameter is running upwards/downwards (with constant step and speed). The run is stopped by releasing the Open/Modify-button.

When the value of the parameter is set into its right value, it can be accepted by moving the cursor to the **Accept** position and pressing **Open/Modify.** The control is then returned to the upper menu level. If the Back-button is pressed in this phase, the control returns to the upper level and the value of the parameter is not changed.

Main Menu

When the **Menu 2/3** -button is pressed in the chart display mode, the following menu will be displayed:



The **>>**-prompt means that there are submenus. When the **Open/Modify** –button is pressed, the submenus will be opened.

Data File

The save parameters of the save data file are set in the Data File –menu
When the **Data File>>** is selected, the following menu is displayed:

There are six choices, and the **Advance Parameters** contains a submenu. The actions of these choices are explained in the following sections.

7.2.5 Advanced Parameters

When **Advanced Parameters >>** is selected**,** the parameters of the data to be stored can be set. The following menu is displayed:

The options of **Distribution Moment** are Current, Number, Diameter, Area, Volume, Mass and RawCurrent:

The Raw currents of each stage are saved always when saving is on (see details of the data format in section 7.3). The calculated moments are based on the raw or fine particle corrected currents depending on the value set to the **Correction** parameter. The correction should always be on.

The options of **Distribution type** are: DW and dlog/Dp.

The options of **Stokes/Aerod** are: Aerodynamic and Stokes.

The options of **Correction** are: On and Off.

The default value of the **Saving Interval** is the value set in the parameter file 1 is 1second.

The default value of the **Dilution Ratio** is the value set in the parameter file. If dilution with a fixed dilution ratio is used the DR will be taken into account in the ELPI+ calculations when the parameter is set to show the dilution ratio.

The default value of the **Density** is the value set in the parameter file.

The type of the collecting plate can be set with the **Sampling** parameter. A new window is opened showing a menu of the possible plate types:

The selection is made with the **Up** and **Down** and **Open/Modify** buttons. This selection does not affect the measured data but is saved in the data file header.

7.2.6 Saving to File

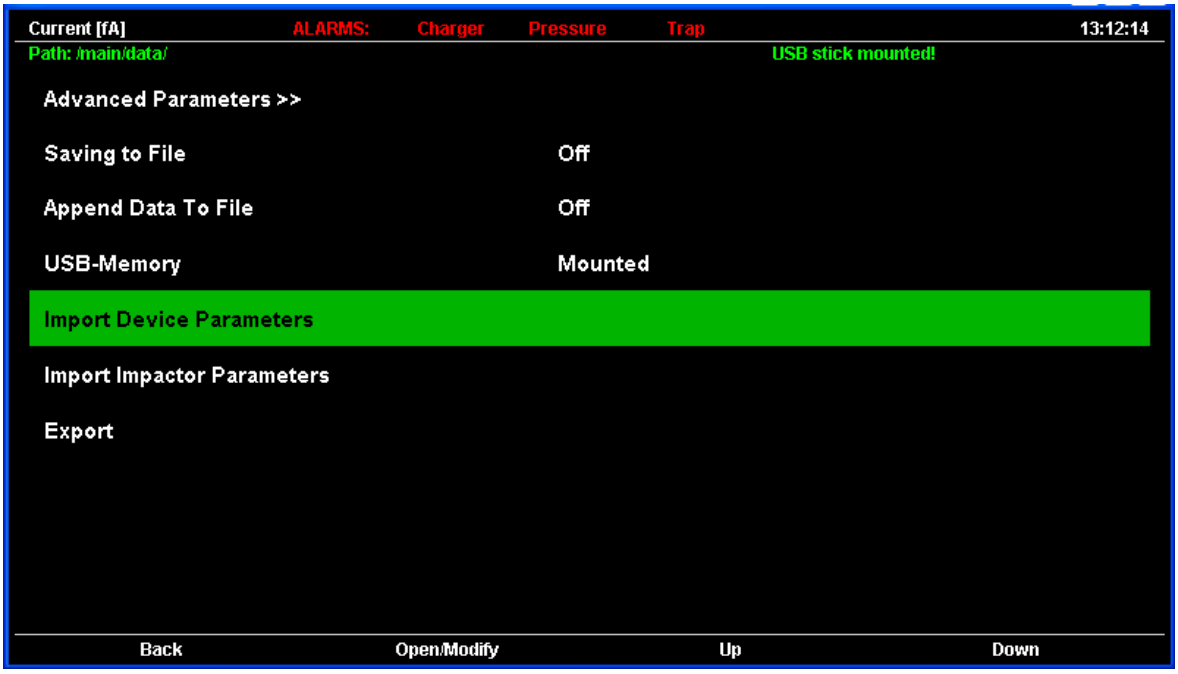
The data saving can be started with the **Saving to File**. The saving can be started also in the graph view, when the **Menu 2/3** has been selected. The saving will be stopped, when the value is set to **Off**.

7.2.7 Append Data to File

Saving to a previous save file can be set with the **Append Data to File** option. If the value is **On**, a new header is written to the existing data file and the data is appended to the file. If this option is **Off**, a new save file is generated always when the saving starts.

7.2.8 USB-memory

With the **USB-memory** option the USB memory stick can be **Mounted** or **Dismounted** for reading of the parameter files to the unit, or for writing of the parameter files and data.



If the mounting of the USB drive is successful, the texts Import and Export change their colors from grey to white. This means that reading from and saving to the USB drive is possible. The data is always saved to the USB stick when saving is on, no data is saved to the internal computer.

7.2.9 Import Device Parameters

When **Import Device Parameters** text is selected, all files named **ParametersDevice_xxxxx.xml** will be read from the USB drive into ELPInux. This operation can't be done if the USB drive has not been mounted (the text is grey).

7.2.10 Import Impactor Parameters

When **Import Impactor Parameters** text is selected, all files named **ParametersImpactor_xxxxx.xml** will be read from the USB drive into ELPInux. This operation can't be done if the USB drive has not been mounted (the text is grey).

7.2.11 Export

When **Export** text is selected, all parameter files will be saved to he USB drive. This operation cannot be done if the USB drive has not been mounted (the text is grey).

Control -menu
When the **Control** option is selected in the main menu, a submenu is opened:

7.2.12 Device controls

Charger, Trap and Flush can have either the value **On** or **Off**. The charger and the flush pump can be set **On** also in the chart view, when the Menu 2/3 has been selected. When measurements are made the charger and the trap should always be on.

7.2.13 Zeroing of the electrometer currents

The zeroing of the electrometer currents starts when **Start Electrometer Calibration** has been selected. The status text **Start** is changed to **Running…** for the duration of the zeroing process. The zeroing parameters can be set in the parameter file. During the zeroing operation the system does not respond to any commands given by the user.

7.2.14 Setting the controller parameters

The parameters of the PID-controller of the impactor low pressure are set by choosing **Pressure PID P, I or D**. A new window is opened where the values can be set. These values should not be changed.

The impactor low pressure set point can be set by choosing **Low Pressure Set Point**. A new window is opened, where the value can be set.

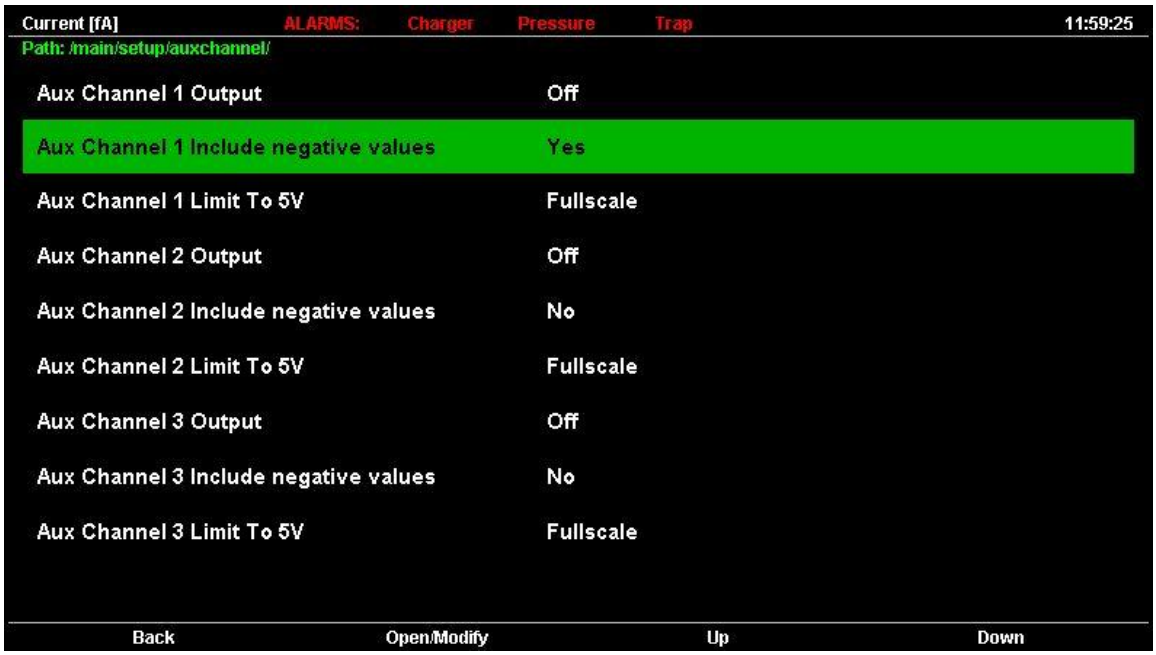
Setup -menu

Selecting the **Setup** option in the main menu will open the submenu below:

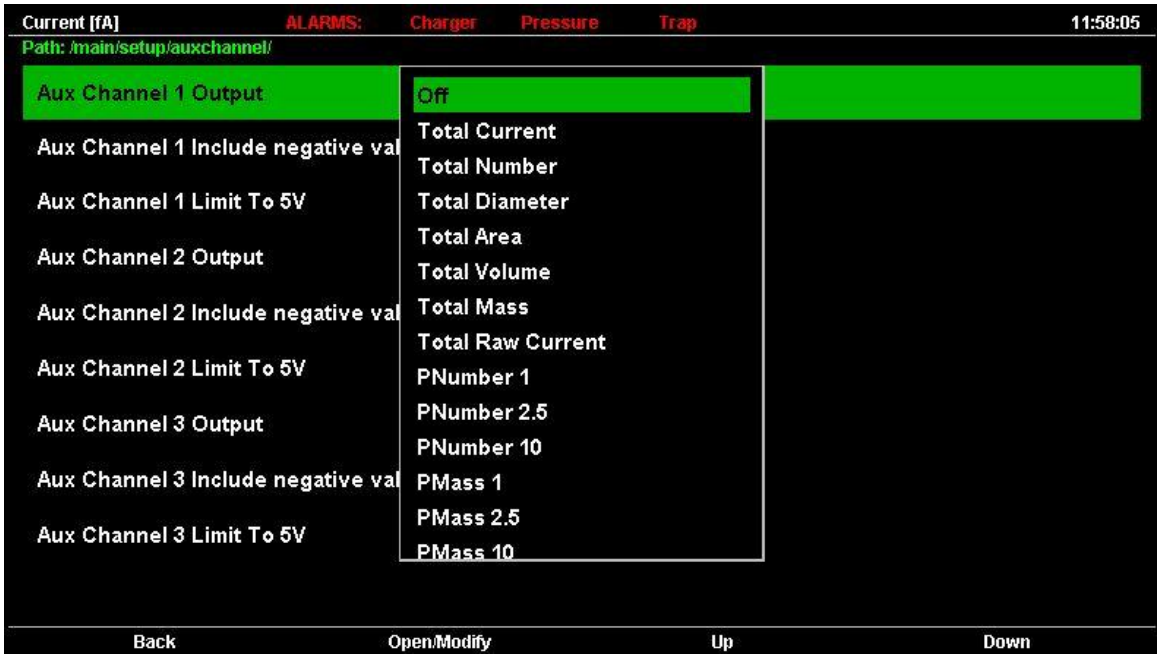
7.2.15 Auxiliary analog channel settings

With Aux Channel Setup the measurement result for the analog auxiliary channels 1, 2 and 3 are defined. There are two options for each channel that can be set. The whole range of the D/A-converter is 10 V (Fullscale 0-10V), which can be reduced to half range of 5 V (Limited 0-5V). It is also possible to set the zero level in the middle of the converters output if negative values are also recorded (Current and raw Current can have negative values).

Aux Channel Setup selection opens a submenu:



When **Aux Channel 1 Output** (or **Aux Channel 2 Output** or **Aux Channel 3 Output**) is selected, the output value can be selected from the list:



Aux Channel 1 Include negative values (or **Aux Channel 2 Include negative values** or **Aux Channel 3 Include negative values**) can have value Yes or No.

Aux Channel 1 Limit to 5 V (or **Aux Channel 1 Limit to 5 V** or **Aux Channel 1 Limit to 5 V**) can have the value Fullscale or Limited.

The following table shows an example, how the output of the auxiliary channel changes, if the total current can have values from 0 to 100 000 fA or from -100 000 fA to 100 000 fA. The voltage output has always a positive value. The output moment maximum value can be set in the parameter file, see chapter 8.

Table 1. Possible combinations of the analog output channels.

	Unsigned		**Signed**	
	Analog output	Total current, example	Analog output	Total current, example
Fullscale	0 V	0 fA	0 V	-100 000 fA
	5 V	50 00 fA	5 V	0 fA
	10 V	100 000 fA	10 V	100 000 fA
Limited	0 V	0 fA	0 V	- 100 000 fA
	2,5 V	50 000 fA	2,5 V	0 fA
	5 V	100 000 fA	5 V	100 000 fA

7.2.16 Impactor Number

When **Impactor Number** is selected, a new window showing all installed impactor options opens:

All parameter files located in the default directory are listed and the character string between _ and .xml (parameter file name should be e.g. Parameters_1234.xml) is shown in the new window.

The impactor number (= Unit number) should be the same in the parameter file as the number string in the file name.

The impactor number is also engraved on the impactor jet plates. The engraving and the impactor number in the parameter file should be the same to ensure proper operation of the ELPI+^{TM}.

When the proper impactor number has been selected, all parameters in that file will be loaded into the system memory and they will be used in the computations.

If the **current** option is selected, the parameters of the current configuration will be used. If the **old** option is selected, the parameters of the previous configuration will be used.

7.2.17 Setting the filter stage on/off

When **FilterStage** is selected, the value toggles from **On** to **Off** or vice versa. The parameter can be set in the parameter file. This should always be ON.

7.2.18 Setting the Auto Zeroing interval

When **AutoZero** is selected, the auto-zeroing period (in hours) of the impactor currents can be set. During the AutoZero procedure the ELPI+™ unit will turn on the flush pump and calibrate the electrometers automatically. The AutoZero Interval defines the time between the Autozero procedures.

7.2.19 IP Address

When Ethernet connection is used for the data saving and unit control, the IP Address of the unit can be seen from here. The IP address can be changed through the parameter file. See chapter 8. Parameter file description for details.

Display

The parameters of the displayed data are set in the **Display**-menu:

7.2.20 Setting the distribution moment

ELPI+ [TM] always saves both the measured current values and the calculated distribution in the data file. The format of the calculated data is defined in **Distribution Moment menu**. Current, Number, Diameter, Area, Volume or Mass concentration can be selected as the shown concentration type:

This option can be also set directly in the chart display mode.

7.2.21 Setting the distribution type

When **Distribution Type** is selected the value changes from DW to dlog/Dp or vice versa.

- dW/dlogDp format is commonly used in displaying size distribution data. If dW/dlogDp is selected the heights of all the channels are divided by the logarithmic width of the channel. As the particle diameter is given in the logarithmic scale the distribution is corrected for unequal channel widths. With dlogDp selected, area of the channel presents the concentration. See more details in Appendix A.
- In dW format the distribution displays the measured concentration value for each size class.

7.2.22 Setting the fine particle loss correction

The use of fine particle correction is set by choosing **Correction**. The parameter toggles from **False** to **True**. Should always be ON.

7.2.23 Setting the backlight level of the display

The backlight level of the display can be set with the **Backlight** option. This opens a new window:

The level can be set into the appropriate level: Level1 is the lowest level and Level 5 is the brightest level.

Log

The log-files saved during the operation of the system can be viewed by choosing **Log** and pressing **Open/Modify**. This opens a new window showing the log-file types. By choosing one of them the list of log-files of this type is shown. The newest log-file is without number.

7.3 Data File Format

ELPI+™ saves data in a *.dat ASCII file that consists of two parts: Header and Data. The Header part of the data file consists of four separate information fields: Measurement info, Impactor data, Charger data and data format.

7.3.1 Header

Header gives general information about the measurement and is mostly user definable

Measurement info

The Measurement info –part of the data file contains information that was put in the Setup-Measurement window before the measurement, and time of the measurement:

```
[ELPI-DATA FILE]
Date=26/10/2010
Time=15:05:06
Location=Dekati ltd
Description=ELPI+ manual
Operator/run=ENI
Cleaned=26/10/2010 15:04
Sampled=greased al-foils
```

Date and time when saving is started.
Location, Description, Operator and Last cleaning time cannot be set in ELPInux. They are stored into the parameter file, from where they are read to the data file. Alternatively they can be set in the ELPI+vi software.

7.3.2 Impactor data

Impactor data values are used in the calculation of concentrations and corrected currents. Correct values can be found in the Impactor Data Sheet delivered with the instrument. If wrong setup values have been used during the measurement, the data should be recalculated with correct setup values using the ELPI+VI Data File Filter program (see more information from the ELPI+VI software manual). These values are uploaded to each ELPI+ unit before shipment.

```
[Impactor Data]
UnitNo=
FlowRate(lpm)=10.000
D50values(um)=0.006,0.017,0.030,0.063,0.109,0.173,0.267,0.407,0.655,
1.021,1.655,2.520,4.085,6.560,9.990
Pressure(kPa)=4.000,10.000,21.900,38.510,68.190,89.170,97.290,99.730,
100.520,101.030,101.200,101.260,101.310,101.330
ResTime=0.010,0.017,0.030,0.053,0.069,0.076,0.078,0.078,0.100,0.100,
0.110,0.120,0.140,0.000
FilterStage=FALSE
```

Unit number	Impactor serial number from Setup Impactor window.
Flow rate	Calibrated instrument flow rate from the parameter file.
D50Values(um)	Calibrated impactor D50 values from the parameter file.
Pressure(kPa)	Pressure calibration values from the parameter file.
ResTime	Residence times in each impactor stage from the parameter file.
FilterStage	Filter stage status (TRUE or FALSE).

7.3.3 Charger data

Charger data is read from the parameter file. Correct values can be found in the ELPI+™ data sheet. If wrong setup values are used during the measurement, the data can be recalculated with correct setup values using the ELPI+VI Data File Filter program.

```
[Charger Data]
UnitNo=A
ChargerSetup=10 lpm
ChargerI(mA)=1.0000
ChargerU(kV)=3.0000
TrapU(V)=0.0000
Efficiency(Dp/mult/exp)=0.0240,5.9410,1.6370,10.0000,1.8190,1.3200,
1.8190,1.3200
```

Unit number	Not implemented
Charger setup	Charger setup information from the parameter file
ChargerI (mA)	Charger current from the parameter file
ChargerU(kV)	Charger high voltage from the parameter file
TrapU(V)	Trap voltage from parameter file
Efficiency(Dp/mult/exp)	Charger efficiency function from the parameter file.

7.3.4 Data format

Data format field tells what type of data has been saved in the data file. This has been selected in the Main->data->advanced->distribution moment before the measurement. If other types of distributions are needed after the measurement, these can be calculated with the ELPIpluscalc software or the ELPI+VI Data File Filter program.

```
[Data Format]
VersionNo=1.0 rev 100
DelimiterChar=,
RawData=Current (fA)
CalculatedMoment=Number (1/cm³)
CalculatedType=dW/dlogDp
Density(g/cm^3)=1.00
StokesDp=FALSE
CalculatedDi(um)=
0.011,0.023,0.043,0.083,0.137,0.215,0.330,0.516,0.818,1.300,2.042,3.208,5
.177,8.095
Correction=TRUE
Dilution=1.00
DataOrder=Date Time (yyyy/mm/dd hh:mm:ss),RAW/Status,Channel1,Channel2,
Channel3,Channel4,Channel5,Channel6,Channel7,Channel8,Channel9,
Channel10,Channel11,Channel12,Channel13,Channel14,
MISC,Charger I, Charger U, Trap U, Impactor low pressure, Aux
channel1,Aux channel2,Aux channel3, ,Aux channel4,Aux channel5,Aux
channel6, Sample air temperature,Electronics temperature,Consentrator air
flow,
CAL,Filterstage,ZeroStage,Stage1,Stage2,Stage3,Stage4,Stage5,Stage6,Stage
7,Stage8,Stage9,Stage10,Stage11,Stage12,
CON,Concentration value,COM,User comment,PM10,PM2.5,PM1,PN10,PN2.5,PN1
```

Version No ELPI+™VI software version number used in the measurement.

Delimiter Char Data delimiter character, comma, space, tabulator or semicolon. Set in the parameter fileIf the ElpiPlusCalc calculation sheet is used, should be set to comma.

RawData Format of raw data. Always Current.

CalculatedMoment Type of calculated values saved in the data file (current, number, diameter, area, volume or mass). Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

CalculatedType Type of calculated data saved in the data file (dW or dlogDp). Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

Density Particle density used in the data calculation. Does not affect raw data. Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

StokesDp Indicates whether Stokes diameter (TRUE) or Aerodynamic diameter (FALSE) has been used in the data calculation. Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

Calculated Di Impactor channels' midpoints. in stokes diameter

Correction Indicates whether correction algorithm for small particle losses has been used in the saved data calculation (TRUE or FALSE). Should always be TRUE if true particle concentration is wanted. Does not affect raw data. Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

Dilution Dilution ratio used in the data calculation. Does not affect raw data. Selected in the Datafile – Advanced Parameters - window before starting the saving of data.

Data order The order of the data in the data rows below.

7.3.5 Data

ELPI+™ data file consist of data rows that are saved at the interval defined in the Datafile – Advanced Parameters - window before starting the saving of data. If the Saving Interval is set for example to the value 10, the time gap between samples is 1 second. Each data row describes the particle size distribution during the time of the sample. Each sample row looks as described below.

```
2000/08/21  13:23:26,RAW/CbTLsfpavZijk,1.123e+01,  1.123e+01,  1.123e+01,
1.123e+01,   1.123e+01,   1.123e+01,   1.123e+01,   1.123e+01,   1.123e+01,
1.123e+01,    1.123e+01,    1.123e+01,    1.123e+01,    1.123e+01,   MISC,
1.000e+00,5.000e+03,4.000e+02,1.000e+01,0.000e+00,0.000e+00,0.000e+00,0.0
00e+00,0.000e00,0.000e00,2.106e+00,0.000e+00,0.000e+00,  CAL,  4.567e+08,
4.567e+08,      4.567e+08,      4.567e+08,      4.567e+08,      4.567e+08,
4.567e+08,4.567e+08,    4.567e+08,    4.567e+08,    4.567e+08,    4.567e+08,
4.567e+08,    4.567e+08,    CON,2.042e+09,COM,User   comment,    4.567e+01,
4.567e+01, 4.567e+01, 4.567e+08, 4.567e+08, 4.567e+08
```

Data rows have the following parts:

1. Date and time. Date and time of the measured sample.

2. `RAW/` indicates that this is raw data (raw current values read from the ELPI unit).

3. Status string is a letter code display for ELPI unit control states:
   UPPERCASE LETTERS = ON
   lowercase letters = OFF

   CbTLsfpavZfff

   C = Charger high voltage status.
   b = Charger switching mode.
   T = Trap voltage status.
   L = Trap high/low.
   s = Trap switching mode.

f = Flush pump status.
p = External pump control status.
a = Data OK.
v = Concentrator / virtual impactor pump.
Z = Zeroing.
i = not in use
j = not in use
k = not inuse

4. Raw/measured current values (Channels 1-14).

5. `MISC` indicates that the next 13 values contain miscellaneous measurement channels (see the Data format –chapter)

6. MISC Channel values: Charger current, Charger voltage, Trap voltage, Impactor low pressure, 6 AUX Channel values, Sample air temperature, Electronics temperature and Concentrator air flow.

7. `CAL` indicates that next 14 values are calculated values. The type of calculated data can be seen in the *Data Format* section of the data file.

8. Calculated concentration values for each stage (Stages 1-14).

9. `CON` indicates that next value is Concentration value. The type of calculated data can be seen in the *Data Format* section of the data file.

10. Total concentration value from the stages 1 to 14.

11. `COM` indicates that next field is user comment.

12. User comment typed in during the measurement in the instrument control section of the main window.

13. PM10, PM2.5, PM1, PN10, PN2.5 and PN1 values.

8 PARAMETER FILE DESCRIPTION

There are two parameter files in the ELPI+ unit. Parameter files include all the necessary parameters for data calculation and saving, including the cutpoints of the impactor stages and the charger calibration curves. If multiple impactors are used in the same ELPI+™ unit, correct parameter files should be selected before the measurement. The
The parameter file has been uploaded to the ELPI+ unit already before shipment. If a new parameter file needs to be uploaded to the unit, import function should be used, see section 7.2.9 for details.
The parameters are divided in to ten groups: Calculation, HW_Control, HeaderInfo, ELPI_IF, Zeroing, Monitor, HAL, DeviceManager, ZeroOffset, IPConfig

```
<Parameter>
  <Group>HeaderInfo</Group>
  <Name>CleanedDate</Name>
  <Type>STRING</Type>
  <Value>dd/mm/yyyy hh:mm</Value>
  </Parameter>
```

Some of the values are user defined, some are calibration values that should be checked from the data sheet and some of the values are constants that should not be changed.

In the following parameter description the user changeable parameters are marked with green color, parameters that can be changed through ELPI+VI software with yellow and calibration values and values that should not be changed with red color, the parameters that are not in use for the moment are marked with blue color. Some of the parameters are Boolean parameters with options 0 for NO/OFF and 1 for YES/ON.

ParametersDevice_xxxxx.xml file consists of following parameters:

Calculation group consists of parameters that affect the concentration calculation:

StokesDpUsed	Stokes (1) or (0) Aerodynamical diameter
CorrectionOn	Correction for fine particle losses On (1) or Off (0)
CalculatedType	Saved moment: Corrected Current (0)/ Number (1)/ Diameter (2)/ Area (3)/ Volume (4)/ Mass (5) / Raw Current (6)
ElectrometerCalibration	Electrometer calibration factor for each electrometer

HW_Control parameters consist of PID parameters for external accessories:

ConcentratorPID	Not in use

Pressure PID_x	Not in use
PressurePID_P	Not in use
PressurePID_I	Not in use
PressurePID_D	Not in use
PressureControlInterval	Not in use
ConcentratorControlInterval	Not in use
ConcentratorPID_I_MAX	Not in use
PressurePID_I_MAX	not in use
ConcentratorPID_MAX_CONTROL	Not in use
PressurePID_MAX_CONTROL	Not in use

Header parameters are mostly user defined, informative parameters that are saved to the data file header. These parameters can either be changed in the parameter file or in the ELPI+VI software:

HeaderLocation	Location of the measurement
HeaderDescription	Description of the measurement
HeaderOperator	Operator of the measurement
DataFormatVersion	Version of the internal software
DataFormatDelimiter	Should be set to comma if excel calculation sheet is used
FileRecordRawData	Save Raw data

ELPI_IF parameters are related to the data communication setting of the ELPI+ unit:

SerialWriteOn	Write to serial port?
TcpWriteOn	Write to tcp port?
FileWriteIntervalInSamples	Saving interval [samples]
RecordedCalculationResult	Moment saved to file
UseLogarithmicData	Logarithmic data saved
TcpListenPort	TCP Port
AddParticleDataToFileFormat	Add PM and PN values to stored data
FileSaveFileName	Prefix of the saving file
FileSaveFilePostfix	Postfix of the saving file
FileSavePath	File save path
FileSaveAppendToOldFile	Append data to the previous file

Zeroing parameters define the electrometer calibration sequence:

ZeroFallTime	Waiting time before zeroing, [s]
ZeroCountTime	Averaging time of zeroing, [s]
AutoZeroInterval	Interval between auto zeroing, [h]

Monitoring parameters:

FileWriteOn	Saving to file On
TrapLowLimit	Alarm, trap voltage, low
TrapHighLimit	Alarm, trap voltage, high
ChargerULowLimit	Alarm, charger voltage, low
ChargerIHighLimit	Alarm, charger voltage, high
ChargerILowLimit	Alarm, charger current, low
ChargerUHighLimit	Alarm, charger current, high

PressureLowLimit	Alarm, impactor low pressure, low
PressureHighLimit	Alarm, impactor low pressure, high

HAL parameters

Aux#Output_LimitOutputTo5V	Aux channel # limited to 5 V
Aux#Output_OutputIsSigned	Negative values possible
SampleTempMeas_mVpC_const	Conv. factor of thermocouple [mV/C]
PressureImpactor_offset	Imp. low pressure sensor offset
PressureImpactor_gain	Imp. low pressure sensor gain
Pressure#2_offset	Ambient pressure sensor offset
Pressure#2_gain	Ambient pressure sensor gain
PressureConcentrator_offset	Not in use
PressureConcentrator_gain	Not in use
SamplingRateInMs	Sampling rate, [ms]
SampleAirTempOffset	Sample temp. sensor offset
ExtraTermoelementOffset	Extra temp. sensor offset

Device Manager

Startup_Aux#On	Aux channel # on at startup
Startup_ConcentratorOn	Not in use
Startup_FlushPumpOn	Flush pump on at startup
Startup_VacuumPumpOn	Vacuum pump on at startup
Startup_TrapOn	Trap on at startup
Startup_CoronaChargerOn	Charger on at startup
Startup_ChargerCurrent	Charger current at startup
Startup_ChargerVoltage	Charger voltage at startup
Startup_TrapVoltage	Trap voltage at startup
Concentrator_SetPoint_lpm	Not in use
Pressure_SetPoint_mbar	Set point of impactor low pressure
BacklightControl	Level of display lighting
Aux#SelectedOutput	Max value of total moment (aux ch #), [fA]
OutputMaxAux#_x	Max value of total moment (aux ch #), [fA]
FlushFanOffDelayTime_s	Not in use

ZeroOffset parameters

ElectrometerZeroOffset#x	Zero offset of channel #, [fA]

IpConfig

IpAddress	IP address of the ELPI+ unit
Gateway	
Netmask	
OverrideIpAddress	
OverrideIpSettings	
UseDHCP	

For details on different options for the Ethernet connection, please see chapter 9 Ethernet connection.

ParametersImpactor_xxxxx.xml file consists of following parameters:

Calculation group consists of parameters that affect the concentration calculation:

Dilution	Dilution factor of the sample
Density	Estimated density of the sample
D50% CutOff #x	Cut points for the impactor stages
Pressure #x	Downstream pressures of the impactor stages
ResTime #x	Residence times of the impactor stages
FilterStageAttached	Not in use, should always be 1
ZeroStageAttached	Not in use, should always be 1
ChargerSetup	Not in use, should always be 1
ChargerEfficiency#x_x	Charger efficiency curve parameters
Flow rate	Flow rate from the data sheet

HW_Control parameters consist of PID parameters for external accessories:

CalibrationTemperature_C	Impactor calibration temperature

Header parameters are mostly user defined, informative parameters that are saved to the data file header. These parameters can either be changed in the parameter file or in the ELPI+VI software:

CleanedDate	Date when the impactor was last cleaned
SamplingMethod	Collection substrate type: Greased Al-foils (0)/ Al-foils (1)/ Bare stage (2)/ Nucle bore (3)/ Filter (4)/ Other (5)
UnitNumber	ELPI+ impactor serial number
ChargerUnitNumber	Not in use

9 ETHERNET CONNECTION

When the ELPI+ is used with ELPIvi via Ethernet connection, the IPconfig parameters in the ParametersDevice file that need to be changed depending on the setup used. Notepad should be used for editing the XML-files.

9.1 Acquiring IP address via DHCP on an Ethernet interface

If the IP address is acquired via DHCP, the address can change when the ELPI+ unit is turned off and again on

UseDHCP: 1
OverrideIpAddress: 1
OverrideIpSettings: 1

In this case the other parameters have no effect.
Import ParametersDevice*.xml file from USB-memory to ELPI+, by first mounting the USB-memory and then choosing Import Device Parameters. Please note that all XML files named ParametersDevice_xxxxx.xml are uploaded to ELPI+.
Select the correct Device file from menu and boot ELPI+ twice. First boot will write /etc/network/interfaces and second boot will enable using the new setup.

9.2 Using fixed IP address

If fixed IP address is used the settings should be as follows:

IpAddress: 10.16.0.26 = the address you want to set
Gateway: 10.16.0.1 = same as in other local devices
Netmask: 255.255.255.0 = same as in other local devices
OverrideIpAddress: 1
OverrideIpSettings: 1
UseDHCP: 0

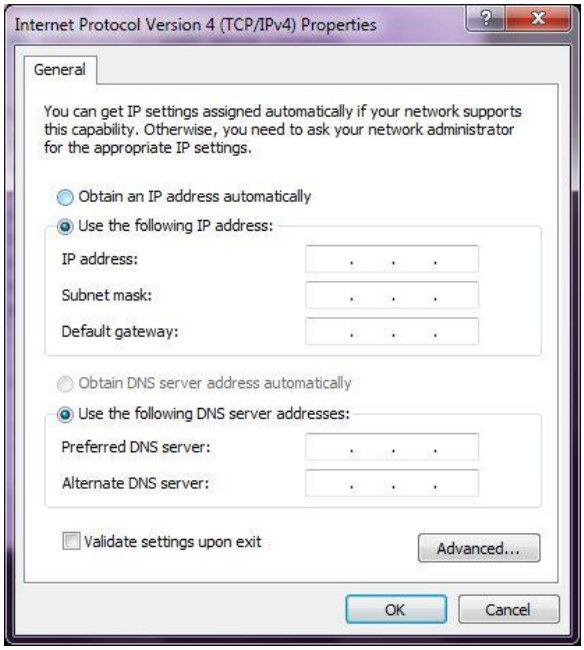
Import ParametersDevice*.xml file from USB-memory to ELPI+, by first mounting the USB-memory and then choosing Import Device Parameters. Please note that all XML files named ParametersDevice_xxxxx.xml are uploaded to ELPI+.
Select the correct Device file from menu and boot ELPI+ twice. First boot will write /etc/network/interfaces and second boot will enable using the new setup.

9.3 Connecting the ELPI+ unit and PC

If PC and ELPI+ are connected together with an ethernet cable between them, then you have to set fixed ip-addresses (see previous chapter) to both of them.

Also Netmasks have to be configured same. For example set address 10.16.0.26 to ELPI+ and 10.16.0.27 to the PC and set netmask 255.255.255.0 to both devices.

Setting the fixed IP address for the PC depends on the operation system, but can usually be found at Contol Panel -> Network Connections/Network and Sharing Center -> LAN properties / Local Area Connection -> Properties -> TCP/IP -> Properties.

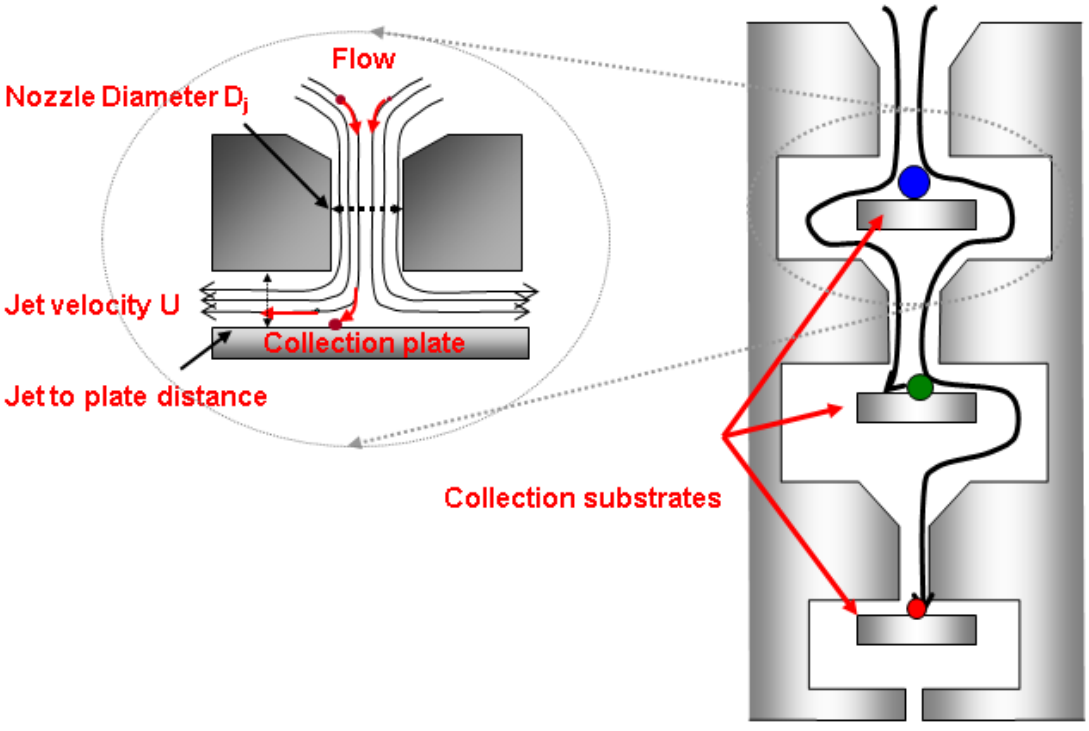

Internet Protocol Version 4 (TCP/IPv4) Properties
General
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.
Obtain an IP address automatically
Use the following IP address:
IP address:
Subnet mask:
Default gateway:
Obtain DNS server address automatically
Use the following DNS server addresses:
Preferred DNS server:
Alternate DNS server:
Validate settings upon exit
Advanced...
OK
Cancel

A PHYSICAL OPERATION

A.1 Particle collection and properties

A.1.1 Impactor

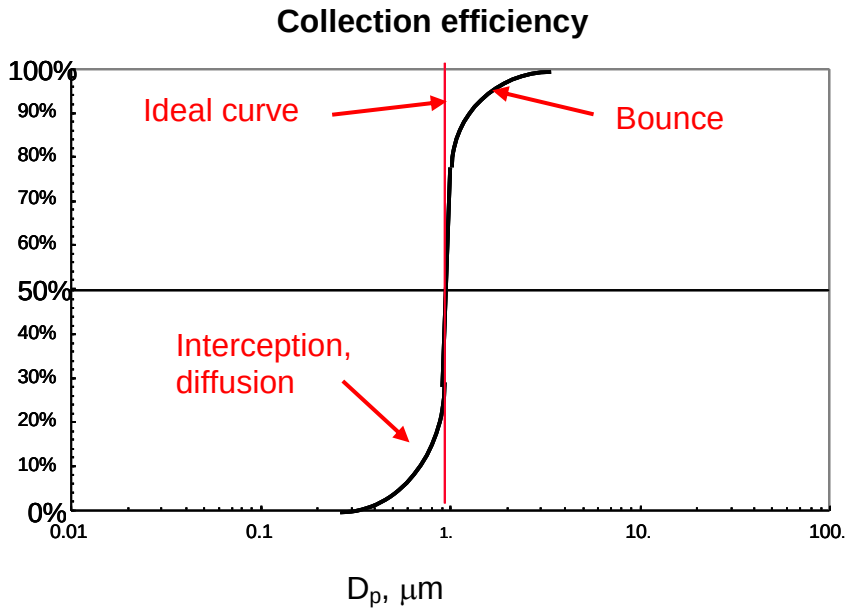
In the ELPI+™ a cascade impactor is used to collect particles size selectively. An impactor is a simple device having two co-linear plates of which the other has a small nozzle in it. The plate with nozzles in it is called the jet plate and the second one the collection plate. Aerosol passes through the nozzles of the jet plate with high speed and makes a sharp turn to flow between the plates. Particles larger than a certain size characteristic to the dimensions of the impactor can't make the sharp turn and impact on the second plate.



Impactor operating principle

Cascade impactors consist of several successive impactor stages with decreasing cut diameters. The highest stage (stage 15) in the Dekati impactor has a cut

diameter of about 10 μm and the lowest impactor stage (stage 2) about 17 nm (see exact values in the impactor data sheet). The lowest stages of the Dekati impactor operate in reduced pressure and so it is also called a low-pressure impactor.
The cut diameter for an impactor is defined as the size of particles collected with 50% efficiency. Ideally the collection efficiency would be a step function so that all particles bigger than certain cut-point were collected on the impactor stage whereas all particles smaller than certain size continued with the flow to lower stages. However, due to bounce and blow-off, some of the bigger particles will go to lower stages than they should, and due to diffusion some of the smaller particles will stay on upper stages than they should. Thus the true collection efficiency of an impactor stage is an S-shaped function.



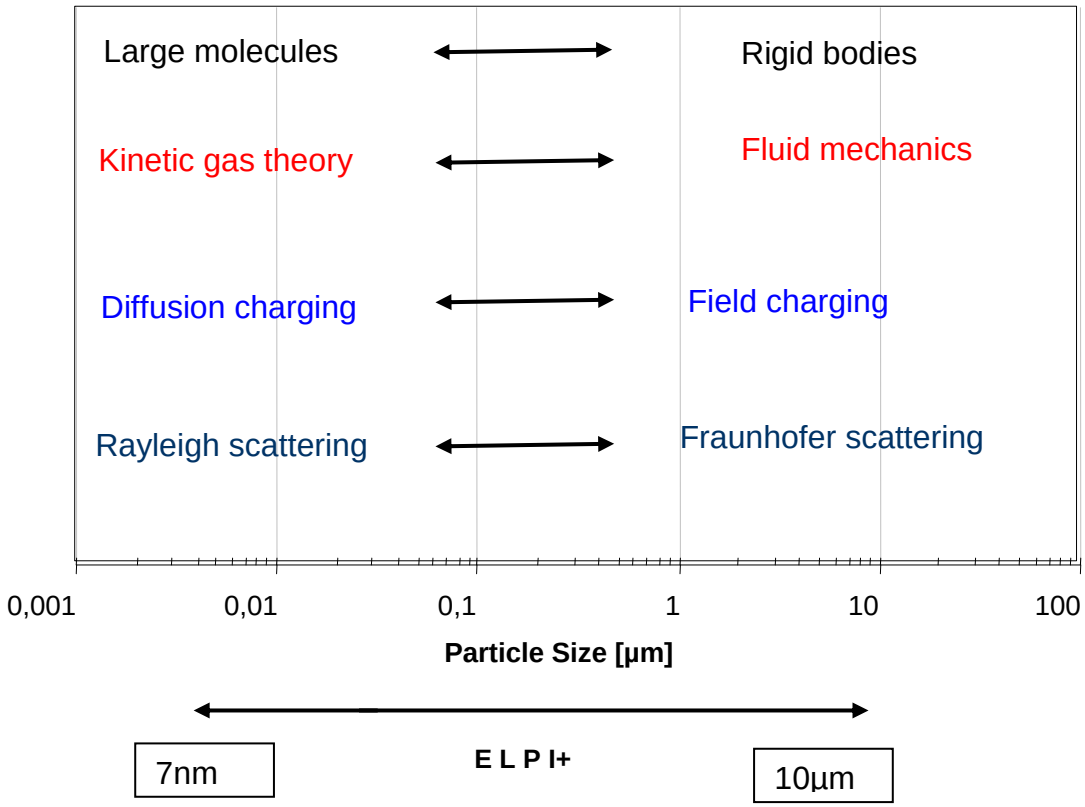
The figure above gives an example of a collection efficiency curve of an impactor stage. The bounce can be reduced in ELPI+™ impactor by greasing the collection substrates or by using the sintered collection plates - diffusional losses on the upper stages of ELPI+™ have been determined and are taken into account in ELPI+™ calculation. The calibration of the ELPI impactor stages and determination of the collection efficiency curves are described in more detail in:

Marjamäki, M., Keskinen, J., Chen, D-R. and Pui, D. Y. H. (2000) Performance Evaluation of the Electrical Low-Pressure Impactor (ELPI), Journal of Aerosol Science 31:2, pp. 249-261.

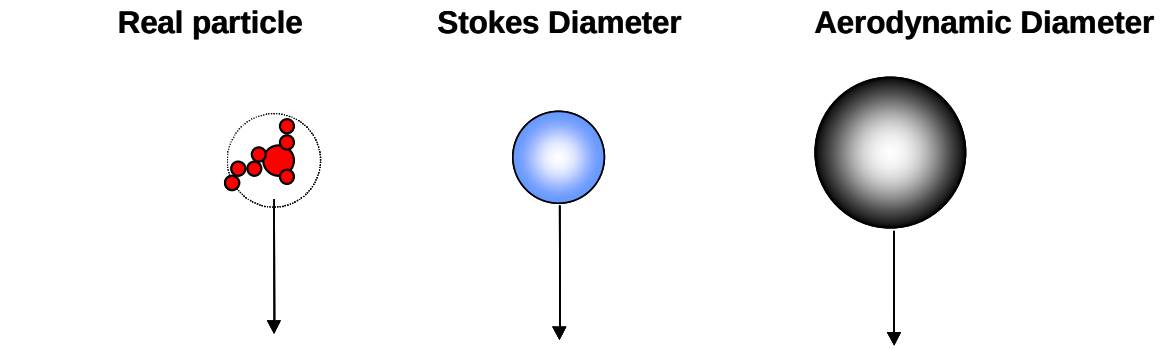
In ELPI+™ the particles are charged in a corona charger before they enter the impactor. These charged particles are then size classified in a 14-stage impactor, and the weak electrical current that arises as the particles are collected on the collection plates is measured from each stage. This way real-time data is gained using the impactor technique.

A.1.2 Particle Size and Shape

Particle size distribution represents a region of five orders of magnitudes. Therefore their behaviour of all these particles cannot be predicted by single equations.



Definition of the particle size is not self-evident. Optical and morphological properties of aerosol particles can have large variations. For this reason different measurement methods can give different results for same aerosol. In impactors size fractionation is based on a quantity called the aerodynamic diameter. It is defined as a diameter of a unit density (ρ_p) spherical particle having the same settling velocity (V_{TS}) as the actual particle. Another widely used definition is the Stokes diameter (D_{ps}), which is the diameter of a spherical particle having the same bulk density and settling velocity as the actual particle.



A.1.3 Particle impaction and stopping distance

Particle flow path through the jet plate nozzle and in the sharply curving gas stream between the jet and the collection plates depends on the inertial forces acting on the particle and friction between the particle and the flowing gas. If the inertial forces are stronger than the frictional forces particle is diverted from the gas stream. If the deviation is large enough particle impacts to the collection plate and is collected. Stopping distance is a useful quantity to estimate how the particles behave when the gas flow changes its direction. It gives the maximum distance (S) that a particle with some initial velocity (V) can travel in still gas

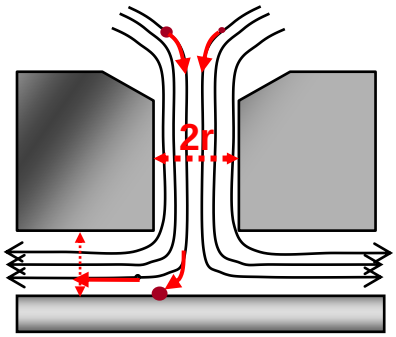
$$S = V\tau$$

Here τ stands for relaxation time. Table below gives stopping distances for selected particles assuming that they have initial velocity of 10 m/s.

Particle diameter	Relaxation time (s)	Stopping distance	Time to travel 95% of Stopping distance (s)
10 nm	6.8×10^{-9}	68 nm	2.0×10^{-8}
100 nm	8.8×10^{-8}	880 nm	2.6×10^{-7}
1 µm	3.6×10^{-6}	36 µm	1.1×10^{-5}
10 µm	3.1×10^{-4}	2.3 mm	8.5×10^{-4}

To collect the smallest particles the gas velocity has to be high. Lowering the operation pressure also helps to collect small particles as thinner gas has a weaker effect on particle motion.
If we calculate the ratio of the stopping distance of a particle to a radius of the jet plate nozzle we get a quantity called Stokes number (Stk).

$$Stk = S/r$$



If the Stokes number is close to the zero particles follow the gas streamlines perfectly. On higher Stokes numbers particles deviate from the gas flow and on some specific value of Stokes number they impact on the collection plate. This critical Stokes number is approximately same for all the stages and is called the Stk_{50} value. For an impactor with round nozzles the Stk_{50} value is about 0.22.

A.1.4 Particle losses in impactor – Correction algorithm

As a result of the small differences in the bombardment of gas molecules from different directions particles have a small wiggling velocity component. In still air it is most clearly seen and is called Brownian motion of the particles. Diffusion is a well-known result of Brownian motion in presence of concentration gradient.

In impactors diffusion causes particles that are smaller than the cut diameter of an impactor stage to be collected to some extent. As the concentration of particles in the gas in the vicinity of the collection plate approaches zero, diffusion creates a net flow of particles towards the collection plate. This phenomenon is characteristic to all instruments using impactor technique, not just the ELPI+™. In gravimetric impactors this phenomenon has negligible effect on the result since the mass of these small particles is often insignificant compared to the actual impacted mass. However, when the particles are detected by their electrical charge, the effect can be significant due to the better sensitivity of the charge measurement.

To overcome these losses an algorithm is used to correct the ELPI+™ reading, as the losses have been measured together with the stage collection efficiency curves. This algorithm is called correction algorithm and it is implemented in the ELPInux and the ELPI+VI™ software. The fine particle correction algorithm corrects both for diffusion and space charger losses. The correction method is described in more detail in:

Virtanen, A., Marjamäki, M., Ristimäki, J., Keskinen, J. (2001). Fine particle losses in electrical low-pressure impactor, Journal of Aerosol Science, vol 32, pp 389-401.

In ELPInux and ELPI+VI software it is possible to save both Raw (Uncorrected) and Corrected particle size distributions. When true particle concentrations are wanted, the correction should always be used.

A.1.5 Impactor loading

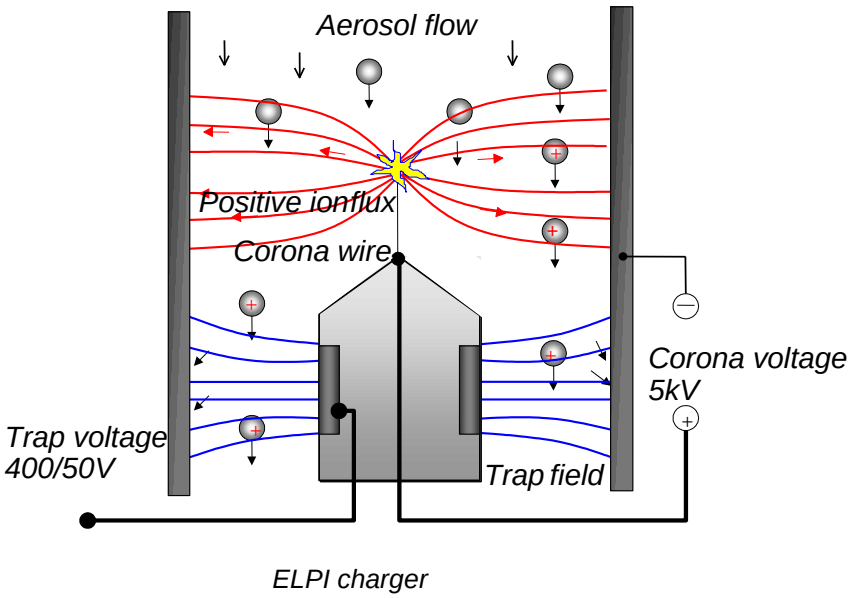
If an impactor measurement continues a long time or sampling is made from a high particle concentration, the high amount of collected particles can have a negative effect on the impactor performance. Properties of the collection plate (or collection foil if used) surface change when it is covered with collected particles. This may lead to an increase in the bounce effect even if the stages were greased. Particles impacting the collection plate bounce off from the surface and back to the gas flow and are collected onto the next stages or pass through the impactor without being collected at all. As the particles bounce from the collection surface they can give their charge or part of it to the stage. Particles can also gain charge from the stage by triboelectric effects.

As the amount of collected particles increases the impacting particles can start to cause re-entrainment of the collected particles. The gas flow pattern changes affecting the cut diameter and finally the stage can even be clogged.

The acceptable amount of collected particle mass depends on the particle size distribution and particle properties and needs to be found out by experience. As a rule of thumb, 1 mg of particles per one impactor stage is absolute maximum. However, this value depends on the type of particles and can be even smaller.

A.1.6 Particle charging

Before the particles are collected in the impactor they must be charged to make electrical detection possible. ELPI+™'s charger uses corona discharge to produce gas ions that can transmit their charge to the particles passing the charger. Corona discharge produces a high number of ions and it is controlled by adjusting the corona current to a predefined value. As a result of the charging process particles will have a known positive charge state that is stable during different operation conditions and high enough to ensure good detection limit.
Most aerosol particles are charged by nature. In processes where particles may have very high charge states it is recommended that they are neutralised before entering ELPI+™. The neutralisation is most critical if the particles have positive polarity. Positively charged particles will have higher than expected charge state after the ELPI+™ charger and they will also have high loss rate in the charger. The charger also removes larger particles and it is not recommended to use ELPI+™ for gravimetric measurement and real time detection AT the same time.



A.1.7 Gas to particle conversion

Some radical gases like SO_2 can interact with the high energy plasma zone created by the corona discharge. Ultra fine particles may be formed during this interaction, which causes measurement artefacts in the ELPI+^{TM}. If gas to particle conversion is suspected a test measurement with pre-filtering of particles is suggested.

A.1.8 Negative current values

The primary quantity that ELPI+^{TM} measures is current. Due to e.g. diffusion of fine particles in the upper stages these measured current values have to be corrected for these losses before calculating the particle number concentration from the current values. These values are designated in ELPI+^{TM} as Raw and Corrected values respectively. (See A.1.4.)
A correction algorithm is used to correct the raw, measured values for the fine particle losses and it is concentration dependent. The correction algorithm transfers part of the measured current signal from the upper stages to the lower ones since part of the signal in the upper stages is caused by diffusion of the fine particles. The more fine particles are detected at the lowest stages, the more losses are assumed in the upper stages. Thus the correction algorithm corrects the raw values more if a large number of particles is detected at the lowest stages of ELPI+^{TM}.

Corrected current values

If you are looking at the corrected current values in the ELPI data, it is possible to have negative values especially in the upper stages of ELPI. This can happen if the average particle size is very small and a low, near zero concentration of coarse mode particles (>2.5 µm) is present. These negative values are caused by the operation of the correction algorithm, correction for the fine particle losses. If no large particles are present all the current measured in the upper stages is

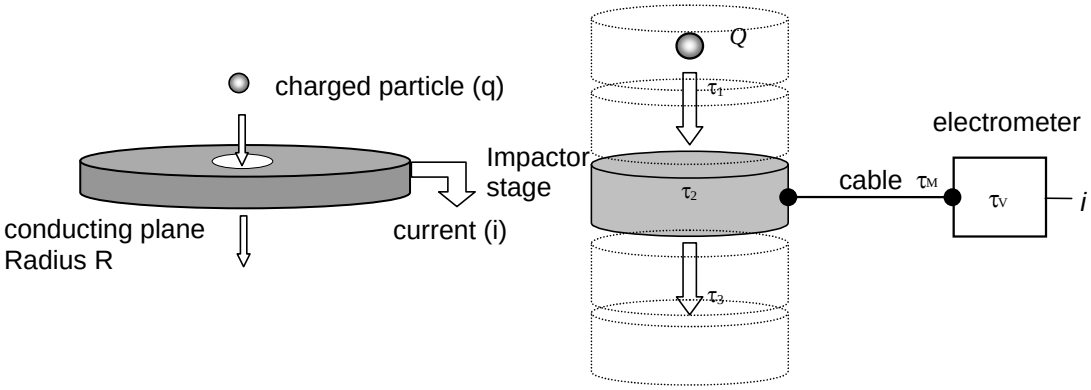
corrected, in some cases over-corrected resulting in negative values. However, negative values in other types of distributions, e.g. number or mass distributions, are saved as zero in the data file.

Raw current values

The raw current values are the measured current values and they are not corrected in any way. The negative values in these are not due to the correction algorithm.

Induced current

In most cases the raw negative current values are caused by sudden changes in sample particle concentration; a charge going through a conducting loop or plate is known to induce a current into a conductor. As the charge approaches the conductor it induces an image charge which is of opposite polarity. If an electric current is measured from the conductor a changing signal is recorded as the charge passes through the conductor. As the ELPI single impactor stage is basically such a conductor and as in the upper stages a majority of current is only passing through the stage and not depositing, a similar phenomenon is seen.



In ELPI readout this can be seen as two current peaks, one negative and one positive. A positive image current peak arises as the positively charged particles enter the stage and a negative current peak is formed as the particles leave the stage. Total current over these two peaks is zero. If the aerosol flow is constant there is the same amount of small particles entering and leaving the stage and no current peak is produced. However when the aerosol concentration changes very rapidly the image current produced by leaving and entering particles may not be cancelled out and a current peak is formed.

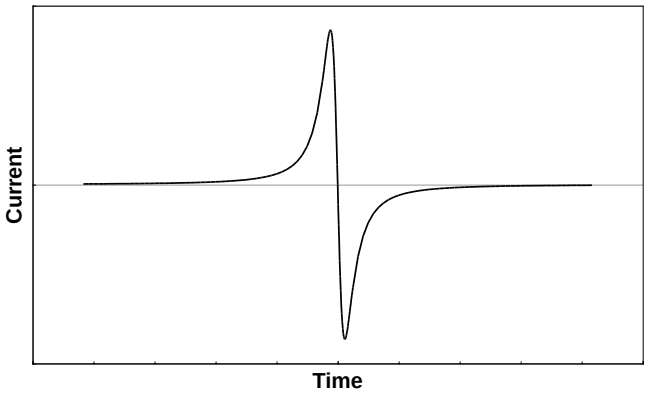


Figure A. Ideal response of a stage to the small charged particles going through the stage.
(M.Marjamäki: TUT report 8-95)

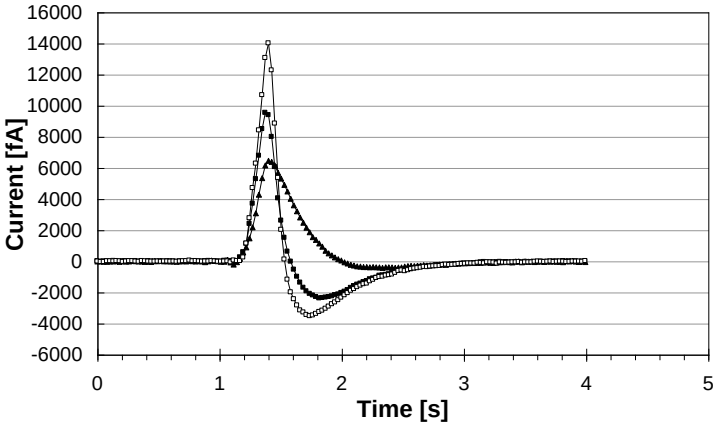


Figure B. A measurement of real induced currents.
(M.Marjamäki: TUT report 8-95)

Electrometer offset

Small negative current can be measured due to electrometer offset in case the noise levels of the electrometers cause most part of the signal. See 4.5 for instructions on how to zero the ELPI+™ electrometers.

Measuring charged particles

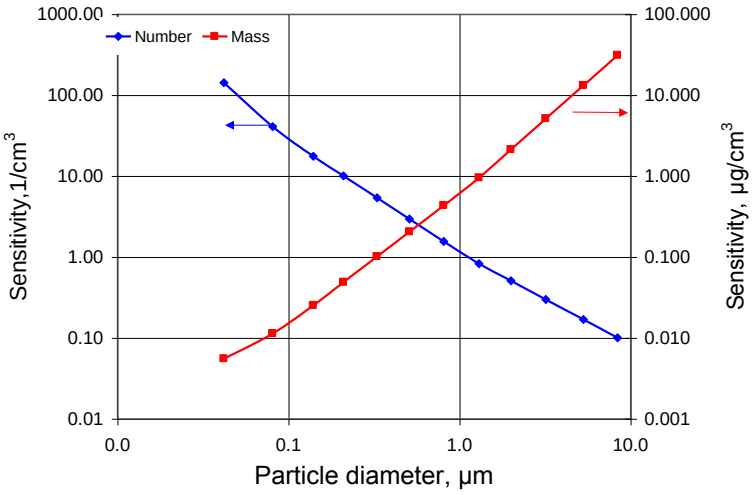
If the ELPI+™ charger is turned off, a reading of negative currents indicate that the particles have a negative charge state. In most cases the original charge of the particles does not affect the ELPI+™ results (when the charger is ON). If the original charge of the particles is negative, the ELPI+™ charger produces a sufficient amount of positive ions to first neutralize and then charge the particles normally, therefore no neutralizer is needed. If the original charge of the particles is positive, in some cases there might be a need to neutralize the particles before they enter the ELPI+™. If the particles originally have a charge level of more than 30-50% of the charge produced by the ELPI+™ charger, use of a neutralizer is recommended. This means that if the current reading with charger OFF is more than 30-50% of the current reading with charger ON, a neutralizer should be used.
If the charger is switched ON the ELPI+™ can be used to measure the original charge of the particles. Note that if particle number concentration is wanted, the ELPI+™ charger must be switched ON.

A.1.9 Measurement accuracy of ELPI+^{TM}

The measurement accuracy of ELPI+^{TM} depends on the size and type of particles that are measured. In ELPI+^{TM} the particles are measured by the charge they carry, so the accuracy of the concentration measurement is the accuracy of the current measurement. Sensitivity is better with large particles since the amount of charge carried with one big particle is significantly bigger than with one small particle.

Noise levels, and measurement accuracy, may be affected by sudden temperature changes or e.g. vibration of the instrument and should therefore be checked before and after each measurement.

Figure 1 presents the accuracy of ELPI+^{TM} measurement when considering both number and mass concentrations for 10 lpm ELPI. As can be seen, the sensitivity with number concentration is better with larger particles, whereas with mass the sensitivity is better with the smallest particles due to the fact that the mass of the larger particles is so much bigger; a small error in number concentration can lead to bigger deviations in mass results.



Measurement accuracy of 10lpm ELPI

When considering the measurement accuracy of ELPI+^{TM}, the effect of measuring conditions such as temperature and gas composition must also be taken into account. The accuracy of the whole particle measurement depends both on the accuracy of the instrument and on the sampling system. Very often the inaccuracy of the measurement is more due to the sampling system than the instrument itself. For example storage effects in sampling systems, deposition and re-entrainment of particles from sampling lines can affect the results. Also varying dilution ratio and/or dilution gas properties may alter the size distribution. Long and twisted sampling lines may lead to significant particle losses due to gravitation, inertial and turbulent impaction, thermophoresis, diffusion and vapour condensation. All these things have to be taken into consideration when evaluating the accuracy of the whole measurement.

A.2 Example of ELPI+^{TM} calculation

This section contains an example of ELPI+^{TM} calculation from current values to selected distribution. Note that this calculation does not consider small particle correction. Only the calculation from current values to aerosol size distribution is presented.
Few things have to be known before it is possible to calculate selected distribution from current values:

Impactor: Aerodynamic D50% values (see impactor data sheet)
Flowrate (see impactor data sheet)
Charger: Efficiency curve (PneQ) (see ELPI+^{TM} data sheet)
Particles: Density
Is Aerodynamic or Stokes diameter wanted
ELPI+^{TM}: Current values
Dilution factor

Used symbols:

Dp_a	Particle aerodynamic diameter
Dp_s	Particle stokes diameter
Di_a	Geometric mean of a channel (Aerodynamic diameter)
Di_s	Geometric mean of a channel (Stokes diameter)
Cc_a	Cunningham's slip correction vector for aerodynamic particle size
Cc_s	Cunningham's slip correction vector for stokes particle size

If we assume that the following startup values are used:

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aerodynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10

Charger efficiency function					
Mult1	5.941	Mult2	1.819	Mult3	1.819
Exp1	1.637	Exp2	1.3201	Exp3	1.3201
Limit1	0.0239	Limit2	10		

Impactor type	
Impactor	10045
Flowrate	10

Density	1
Dilution	1

Then Cunningham's slip correction factor is calculated using equation

$$C_{Ca} = 1 + \left(\frac{2}{76 * Dp_a}\right) * (6.32 + 2.01 * e^{-0.1095 * 76 * Dp_a})$$ for each D50% value (76=pressure in cmHg)

Now we have the Cunningham's slip correction factor for each D50% value:

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166

We calculate also geometric mean of each channel, which is called Di (Di_n equals Di of channel n)

$$Di_n = \sqrt{Dp_n * Dp_{n+1}}$$

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_a	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699		

Next, we must find the same values for particle Stokes diameters. Iteration must be used to find out the stokes diameter.

$$Dp_s = \frac{Dp_a}{\sqrt{Density * \frac{Cc_s}{Cc_a}}}$$

Where Cc_s is again

$$C_{Cs} = 1 + \left(\frac{2}{76 * Dp_s} \right) * (6.32 + 2.01 * e^{-0.1095 * 76 * Dp_s})$$

Now we have the following values for the impactor stages:

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_a	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699		
Stokes	Dp_s[µm]	0.006	0.017	0.030	0.0600	0.108	0.170	0.260	0.400	0.640	1.000	1.600	2.500	4.400	6.8	10
	Cc_s	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_s	0.0100	0.0154	0.0294	0.0574	0.0997	0.1591	0.2500	0.3994	0.6391	1.0182	1.6181	2.6926	4.4508		

At this point we have to decide if aerodynamic or stokes particle size is used. Let's assume that it is aerodynamic:

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	
	Di_a	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699		
Stokes	Dp_s[µm]	0.006	0.017	0.030	0.0600	0.108	0.170	0.260	0.400	0.640	1.000	1.600	2.500	4.400	6.8	10
	Cc_s	37.1057	19.6398	11.2747	5.8383	3.4773	2.4547	1.8844	1.5432	1.3282	1.2073	1.1287	1.0821	1.0465	1.0300	
	Di_s	0.0100	0.0154	0.0294	0.0574	0.0997	0.1591	0.2500	0.3994	0.6391	1.0182	1.6181	2.6926	4.4508		
Di [µm]		0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699		

Then, we calculate a dlogDp multiplier vector

$$dlogDp = \log_{10} \frac{Dp_{n+1}}{Dp_n}$$

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_a	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
Stokes	Dp_s[µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_s	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_s	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
Di [µm]		0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
dlogDp		0.4523	0.2467	0.3010	0.2553	0.1970	0.1845	0.1871	0.2041	0.1938	0.2041	0.1938	0.2455	0.1891	0.1675	

Where Di values are either stokes or aerodynamic values, depending on the selection.

Finally, we calculate the conversion vector X from current to number. Now we need the charger efficiency function.

Charger efficiency function is a three-part power fit and it is a result of calibration values P*n and constants e and Q where:
P = Charger penetration
n = average charge per particle
e = elementary charge ($1.602*10^{-19}$ C)
Q = Calibration flow rate (10lpm)

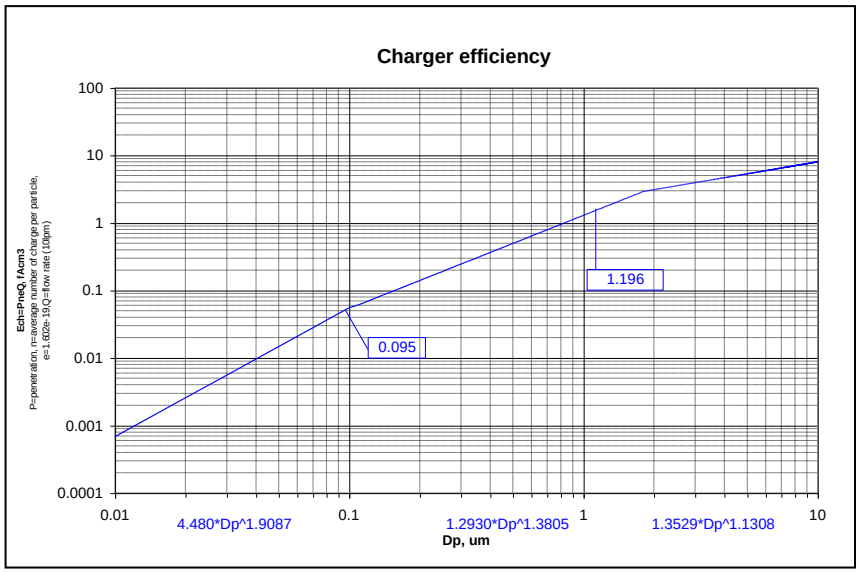
P*n values are originated from article
Marjamäki, M., Keskinen, J., Chen, D-R. and Pui, D. Y. H. (1999) Performance Evaluation of the Electrical Low-Pressure Impactor (ELPI), Journal of Aerosol Science 31 (2) (2000) pp. 249-261.

Giving us the efficiency function:

Di < 0.095 µm:

$X(Di) = 4.48Di^{1.9087}$

$0.095\mu m < Di < 1.196$



The charger efficiency curve is calibrated using flowrate of 10lpm, so we must reduce the efficiency curve to a real flow.

For example, stage 1: Di_s=0.0291 (less than 0.095), Flow rate = 9.71, Charger efficiency as above:

$$X = 4.48 * Di_s^{1.9087} * \frac{Flowrate}{Calibrationflow} = 4.48 * 0.0291^{1.9087} * \frac{9.71}{10}$$

Note that **Stokes** Di is used, because the charging process is dependent on the particles stokes diameter. That's why it is always necessary to estimate the particle density and calculate the particle stokes diameter.

Impactor properties		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aero-dynamic	Dp_a [µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_a	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_a	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
Stokes	Dp_s[µm]	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8	10
	Cc_s	37.1057	13.4843	7.9175	4.3070	2.7393	2.0539	1.6631	1.4205	1.2603	1.1663	1.1039	1.0665	1.0378	1.0245	1.0166
	Di_s	0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
Di [µm]		0.0136	0.0226	0.0424	0.0805	0.1355	0.2102	0.3225	0.5060	0.8000	1.2649	2.0000	3.3166	5.4699	8.2462	
dlogDp		0.4523	0.2467	0.3010	0.2553	0.1970	0.1845	0.1871	0.2041	0.1938	0.2041	0.1938	0.2455	0.1891	0.1675	
X, fAcc		0.0052	0.0120	0.0281	0.0654	0.1300	0.2321	0.4083	0.7400	1.3549	2.4806	4.5417	8.8553	17.1412	29.47	

We are able to form all conversion vectors :

Number dN/dlogDp [1/cm³]	1/X*1/dlogDp*Dilution
Diameter dD/dlogDp [µm/cm³]	1/X*Di*1/dlogDp*Dilution
Area dA/dlogDp [µm²/cm³]	$1/X*Di^2$ * **TT** * 1/dlogDp*Dilution
Volume dV/dlogDp [µm³/cm³]	$1/X*Di^3$ * **TT** *(1/6)*1/dlogDp*Dilution
Mass dM/dlogDp [mg/m³]	$1/X*Di^3$ * **TT** *(1/6)*1/dlogDp*Dilution*Density*0.001
Number N [1/cm³]	1/X*Dilution
Diameter D [µm/cm³]	1/X*Di*Dilution
Area A [µm²/cm³]	$1/X*Di^2$ * **TT** *Dilution
Volume V [µm³/cm³]	$1/X*Di^3$ * **TT** *(1/6)*Dilution
Mass M [mg/m³]	$1/X*Di^3$ * **TT** *(1/6)*Dilution*Density*0.001

Conversion vectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number dN/dlogDp [1/cm³]	422.4522	337.9666	118.3627	59.9285	39.0460	23.3455	13.0898	6.6202	3.8080	1.9749	1.1360	0.4600	0.3086	0.2026
Diameter dD/dlogDp [µm/cm³]	5.7481	7.6324	5.0217	4.8241	5.2907	4.9081	4.2213	3.3496	3.0464	2.4981	2.2720	1.5255	1.6879	1.6706
Area dA/dlogDp [µm²/cm³]	0.2457	0.5415	0.6693	1.2200	2.2522	3.2417	4.2768	5.3243	7.6565	9.9271	14.2754	15.8952	29.0054	43.2800
Volume dV/dlogDp [µm³/cm³]	0.0006	0.0020	0.0047	0.0164	0.0509	0.1136	0.2299	0.4490	1.0209	2.0928	4.7585	8.7864	26.4429	59.4826
Mass dM/dlogDp [mg/m³]	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004	0.0010	0.0021	0.0048	0.0088	0.0264	0.0595
Number N [1/cm³]	191.0741	83.3670	35.6307	15.2981	7.6930	4.3078	2.4489	1.3513	0.7381	0.4031	0.2202	0.1129	0.0583	0.0339
Diameter D [µm/cm³]	2.5998	1.8827	1.5117	1.2315	1.0424	0.9057	0.7898	0.6837	0.5905	0.5099	0.4404	0.3745	0.3191	0.2798
Area A [µm²/cm³]	0.1111	0.1336	0.2015	0.3114	0.4437	0.5982	0.8001	1.0868	1.4840	2.0263	2.7669	3.9025	5.4837	7.2490
Volume V [µm³/cm³]	0.0003	0.0005	0.0014	0.0042	0.0100	0.0210	0.0430	0.0916	0.1979	0.4272	0.9223	2.1572	4.9992	9.9628
Mass M [mg/m³]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0009	0.0022	0.0050	0.0100

Now when we multiply the current values vector with these conversion vectors we get the selected distribution. For example consider the following values:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Di_a	0.006	0.017	0.03	0.06	0.108	0.17	0.26	0.4	0.64	1	1.6	2.5	4.4	6.8
Current values	585.69	1233.40	4571.91	12232.4	29672.2	36239.5	68540.1	80523.3	80747.2	44362.2	23538.5	8385.29	585.69	1233.40
Conversion vector from current to number distribution (dN/dlogDp) from above	422.4522	337.9666	118.3627	59.9285	39.0460	23.3455	13.0898	6.6202	3.8080	1.9749	1.1360	0.4600	0.3086	0.2026
Number distribution (dN/dlogDp)	247426	416848	541143	733069	1158580	846029	897176	533080	307485	87610	26739	3857	1404	621

And we get the number distribution.

Terms

Number distribution
Number distribution is formed by multiplying the current distribution with the conversion vector.
[dN] = [Ci] * [(1/Xi(Di))]

1/dlog(Dp*)*
Aerosol distributions are normally given in the 1/dlog(Dp) mode. It is formed by dividing the stages measured value by the logarithmic width of the stage. In 1/dlog(Dp) mode the area of the histogram gives the value in each size range.
[dN/dlog(Dp)] = [dN] * [(1/dlog(Dp))]

Diameter distribution
Diameter distribution gives the total diameter of all particles in each size range. It is formed by multiplying the current distribution by the conversion vector and by a vector formed from the midpoint values (Di) of each stage.
[dD/dlog(Dp)] = [Ci] * [(1/Xi(Di))] * [Di] * [(1/dlog(Dp))]

Area distribution
Area distribution gives the total surface area of all particles in each size range. It is formed by multiplying the current distribution by the conversion vector and by a vector formed from the surface areas of spheres having diameter equal to midpoint values (Di) of each stage.
$[dA/dlog(Dp)] = [Ci] * [(1/Xi(Di))] * [\pi * Di^2] * [(1/dlog(Dp))]$

Volume distribution
Volume distribution gives the total volume of all particles in each size range. It is formed by multiplying the current distribution by the conversion vector and by a vector formed from the volumes of spheres having diameter equal to midpoint values (Di) of each stage.
$[dV/dlog(Dp)] = [Ci] * [(1/Xi(Di))] * [{}^1/_6 * \pi * Di^3] * [(1/dlog(Dp))]$

Mass distribution
Mass distribution gives the total mass of all particles in each size range. It is formed by multiplying the current distribution by the conversion vector and by a vector formed from the masses of spheres having diameter equal to midpoint values (Di) of each stage. Note that mass distribution is scaled to unit mg / m^3.
$[dV/dlog(Dp)] = [Ci\ ] * [(1/Xi(Di))] * [{}^1/_6 * \pi * Di^3 * Density] * [(1/dlog(Dp))] * 10^{-3}$

A.2.1 Using different density values in the ELPI+™ calculation

By default the ELPI+™ and the ELPI+VI software use density value of one (1) for the particles in the calculation of particle concentrations and size distributions. This is a good estimate in most applications and the results can be considered reliable. If it is known, however, that the particle density is something else than 1g/cm^3, this density value can be used in the ELPI+™ calculation. In this case, there are two options: Aerodynamic and Stokes:

- If Aerodynamic is selected: the charging efficiency is calculated with the corresponding Stokes diameter, impactor cutpoints and midpoints are calculated with Aerodynamic diameter (corresponding to density=1), dlogDp vector is calculated with Aerodynamic diameter.
- If Stokes is selected: charging efficiency, impactor cutpoints and midpoint, and dlogDp vectors are all calculated with the Stokes diameter corresponding to the given density value.

Particle charging depends on the particle Stokes diameter, which is why charging efficiency is always calculated with the Stokes diameter. Also, it should be kept in mind that impactors always classify particles according to their Aerodynamic diameter.

Filter stage extends the ELPI+™ measurement range down to 6nm. The filter stage is a back-up filter put under the other impactor stages. The filter stage lower cutpoint, 6nm, is fixed and is not changed even if Stokes diameter and different density values are selected. This is because of the different operation of the filter stage from the other impactor stages, and the fact that particles smaller than 6nm don't get through the ELPI+™ charger. Therefore it is not justified to decrease the lower cutpoint just by using differet density values in the calculation.
If high density values are selected when the filter stage is used, and Stokes is selected as the diameter type, the impactor cutpoints are recalculated with this given density value. With >1 density values the cutpoint decrease from the calibrated values given in the data sheet. If the density is increased enough, the lower cutpoint of impactor stage 1, i.e. upper cutpoint of filter stage can be lower than 6nm, i.e. the lower cutpoint of the filter stage. This, however, cannot be true based on the operating principle of the ELPI+™.
If high density values are used when filter stage is installed in the instrument, and Stokes diameter is selected, the new impactor cutpoints are first calculated. If, in this situation the lower cutpoint of the impactor stage 1 is smaller than 6nm, an error message appears in the software. The results cannot be calculated with these values because of the characteristics of the physical operation of the instrument.

B ELPI+™ ACCESSORIES

ELPI+™ accessories. Please contact Dekati ltd for more information.

ELPI+ ™ Spare Impactor and Charger unit
Insulator ring set for ELPI+ impactor
DEKATI impactor collection plate set
Impactor collection plate set, 14pcs
Vacuum hose (1,5 m) pressure valve + NW16 flange connectors
ELPI+ power supply
Corona needle
ELPI+ filter stage block
Substrate positioning tool
Leakage test tool
ELPI+ inlet connector with o-ring
O-ring set for ELPI+ impactor
Dekati Fine Particle Sampler
Dekati diluter
Sampling cyclone

C ELPI+™ SUPPORT

Dekati ltd encourages you to comment on the products we make. Please fill out the following forms and send them to Dekati ltd:

Mail to:

Dekati ltd
Osuusmyllynkatu 13
FIN-33700 Tampere
Finland

Fax to: Dekati ltd
+358-3-3578140

email: support@dekati.fi

Documentation comment form

Dekati ltd encourages you to comment on the documentation supplied with our products. This information helps us provide quality products to meet your needs.

ELPI+vi ™ version and revision number: _____
ELPI+vi ™ Help file version number: _____
ELPI+ ™ User manual version number: _____

Please comment on the completeness, clarity and organization of the manual and help files

_____
_____
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If you find errors in the manual or in the help files, please record the page numbers and describe the errors

_____
_____
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Thank you for your help.

Name: _____ Title:_____
Company: _____
Address: _____
_____
phone: _____ fax:_____
email: _____

ELPI+™ Technical support form

If you find any troubles or errors concerning the ELPI+™ unit or ELPI+vi ™ Measurement program please provide us the following information.

Used external computer:
Processor: _____ Clock Speed:_____
RAM: _____ Hard disk: _____
Operating System: _____ Version number: _____
Video board/driver: _____

Other adapters:

Hardware:	IRQ	DMA	Base I/O Address	COMport:
_____	_____	____	_____	_____
_____	_____	____	_____	_____
_____	_____	____	_____	_____

ELPI+vi ™ version: _____ ELPI+ ™ unit number: _____

Problem description:
_____
_____
_____

Error messages (if any):
_____
_____
_____

log file messages:
_____
_____
_____

Steps to reproduce problem:
_____
_____
_____

Thank you for your help.

Name: _____ Title:_____
Company: _____
Address: _____
_____
phone: _____ fax:_____
email: _____

ELPI+™ comment form

Please give us some comments on the ELPI+™. This information helps us provide quality products to meet your needs.

ELPI+™ unit _____
ELPI+vi ™ Measurement program _____

ELPI+vi ™ version and revision number _____
ELPI+™ unit number: _____

Please comment on the ELPI+™ unit (Mechanics, user interface):

_____
_____
_____
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Suggestions for the ELPI+vi ™ Measurement program:

_____
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Thank you for your help.

Name: _____ Title:_____
Company: _____
Address: _____
_____
phone: _____ fax:_____
email: _____

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